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LOCOMOTIVE TERMINALS.

A DISCUSSION OF THE ARRANGEMENT, DESIGN, CONSTRUCTION AND OPERATION OF LOCOMOTIVE TERMINAL FACILITIES TO OBTAIN THE GREATEST EFFICIENCY.

Introduction.

The efficiency of the motive power department is generally determined, first, by the average percentage of the total number of locomotives owned that are ready for the use of the transportation department; second, by the number of engine failures; and third, by the cost of locomotive repairs and maintenance.

In an attempt to improve any or all of these features it will be found that the problem divides itself into four general parts: (1) The design of the locomotive; (2) repair shops; (3) engine houses, and (4) operation on the road. Of these, the first is usually beyond control as far as immediate results are concerned, but the other three are capable of showing quick returns if carefully analyzed.

It is the purpose of this series of articles to discuss in all its details the third factor, *i. e.*, locomotive terminals. It is this point that is very largely responsible for engine failures and the cost of maintenance, and it is principally responsible, so far as the motive power department is concerned, for the percentage of time that the locomotives in service are ready for the use of the transportation department. Careful study of the many operations and arrangements at the different division points will probably result in a greater immediate improvement in the general efficiency than would be possible in any other way. The others are important — very important — but the design and condition of the division terminals is usually the weakest feature on most roads.

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General Conditions.

There are probably no two locomotive terminals in the country, even those on the same road and on the same division, that present exactly the same problems in all respects and, taking the country as a whole, the conditions are so different in various sections as to make it the height of folly to erect structures and adopt methods in California or Georgia that would be perfectly suited to the conditions in Montana or Maine. The colder climates complicate the problem and warmer climates simplify it greatly.

Another feature that influences the decision as to the way to obtain the best results is a fairly accurate idea of the number of locomotives to be handled per day and the class of service in which they are engaged. A terminal that turns 200 locomotives in 24 hours, practically all freight, would of course not be well suited for turning 25 engines in mixed service; not only would the size of the house be different, but the organization of the forces and the methods of doing the work would be altered.

Class of traffic on the road and the methods of despatching have a decided influence on the best methods of handling a locomotive terminal. The grade of water used for boilers on a division sometimes makes a very great difference in the scheme of operation. If boilers have to be washed every seven days a type of engine house differing in detail as well as different methods will be required than when boilers are washed once in 30 days and then only to comply with the law. Assigned or pooled locomotives influence the problem; labor conditions in the vicinity, the cost of ground and shape of the plot also have to be taken into serious consideration.

All of these varying conditions and others, such as distance to the main repair shop and quality of the fuel, which will readily suggest themselves, make it impossible to say that any one kind of structure or any particular way of doing the work or of organizing the force is universally the best.

General Principles.

In spite of the various conditions mentioned above it is possible to formulate some general rules that are applicable in every case. Their application may and should differ at different points, but the rules themselves can be accepted as sound.

In the first place, the basis of efficiency of a locomotive terminal is *time* and everything should be considered with the idea of arranging for the shortest possible number of minutes between uncoupling the engine from its train and coupling it on again. This, as far as the mechanical department on most roads is concerned, means the shortest interval from crossing the switches to go to the coal chute to the time it is ready to again go to the yard.

To obtain the best results in saving time between the yard

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switches and the turntable it is desirable that any locomotive stand still at any one point the minimum length of time to complete any single operation. The clinker pit will probably require the maximum period of delay on any individual locomotive, but if it is of sufficient size and a sufficient force is employed the average time at this point per locomotive can be brought to a very reasonable figure, probably not more than the average delay at other points, such as coal chute or stand pipe. If this is not the case, then there is no objection to delaying the locomotives at other points for the same length of time. If, assuming that locomotives are coaled singly, it takes between three and five minutes to locate the engine under the chute and take on coal, the average delay at any other point should not be greater than this, which, of course, means that the cinder pit and the force operating it shall be large enough to take care of sufficient engines at one time to permit the average delay at this point to equal that at the coal chute. Where several are coaled at once then the average time will probably be less than would be practical at the cinder or inspection pit and sand and water could be taken at the same stop. It is not usually advisable, however, to perform these three operations at one stop.

After entering the house the same time basis will still apply and every necessary operation should be arranged to be performed as quickly as possible consistent with good work. At points where poor boiler water has to be used and it is necessary to wash out at fairly frequent intervals this operation will probably be the longest single one that is customarily performed and it is practically compulsory in such cases to provide a blowing down system of a capacity to empty a boiler with steam at 180 lbs. pressure in not more than 30 minutes; also to provide water for washing out with a pressure of at least 100 lbs. and a temperature of about 150 degs. Provision for then filling the boiler with water at a temperature of 190 degrees and a supply of steam for use if desired, with at least 100 lbs. pressure, will be found to be of great advantage. When appliances of this kind are provided and an efficient fire kindler is used it should be possible to bring an engine in, thoroughly wash the boiler and have it again on the turntable with a good fire and 100 lbs. of steam in not to exceed two hours under normal conditions.

Other general principles that are applicable in all cases are—that the house should be well lighted, both by natural and artificial light; the floor should be in good condition and perfectly drained so that it will be impossible for pools of water to collect; that in cold weather a supply of heat be provided that will keep the house at a comfortable temperature under all reasonable circumstances and so arranged that the machinery of a locomotive will be rapidly dried out and the workmen will be able to quickly warm themselves after having been out in the cold. The ventilation should be such as to keep the house comparatively clear of smoke and steam under all ordinary conditions. Work benches, small stores, tools that are often used, emery wheels, etc., should be provided at convenient points throughout the house to reduce the amount of travel back and forth to a minimum.

Comfort of the workmen—not so much their physical comfort except as that influences their mental condition—but a satisfied feeling throughout the force, is a most important factor in efficient engine house work. Lockers, wash and toilet rooms, kept in first-class condition, are necessary adjuncts to all modern engine houses and should not be overlooked in any case. Where the piece or bonus method of payment is in use the times and prices should be based on the facilities and conditions at each place. If the day rate is in force, good sound horse sense in dealing with individual cases is essential.

Even with the very best conditions, as outlined to some extent above, unless the organization of the force is on a sound basis, the results will be unsatisfactory, but if the engine house force is properly organized, excellent results can be obtained with very ordinary conditions. It is impossible to lay down any set rules for the organization of terminal forces which would fit all cases except to say that the path of responsibility be direct and clearly defined. Each foreman, and indeed each workman, should have his duties clearly set forth and be held entirely responsible for their satisfactory performance. It has been proven that ample supervision, instead of being a heavy charge for non-productive labor, will prove to be a decided saving because of increased efficiency.

Track Arrangement.

Cost of the ground, shape of the plot and capacity of the terminal have so large an effect upon the relative location of the different buildings and the location of the tracks in the neighborhood that but a few general principles can be given as universally applicable. In the first place the arrangement should be such that when the locomotive starts for the turntable it will receive coal, sand, water, be inspected and have the fire and ash pan cleaned without any switching and on a direct line. Arrangements should be made so that it will be possible to pass any locomotive around those that may be ahead of it and on to the turntable after completing any one or more of these various operations. There should be separate tracks for incoming and outgoing locomotives, with either cross-overs or special arrangements, so that, if necessary, outgoing engines can undergo the same operations as incoming locomotives. This is best arranged by having a small cinder pit on the outgoing track separate and distinct from the main cinder pit, although located adjacent to it; one or more water stand pipes on the outgoing track and a cross-over in the case of a trestle coal chute or a separate hopper in the case of a multiple track chute for coaling.

Standing tracks for storing locomotives which either do not have to go into the house at all or have been given the attention required in the house and are ready for service, but are not yet ordered, should be provided and arranged to permit any locomotive standing on them to reach the outgoing track without inconvenience. While most of the locomotive terminals that have been designed in the last six or eight years have an arrangement of tracks which, as conditions will permit, include most of the ideas mentioned, we only present three of the latest examples built, all of which are located on the Boston & Albany Railroad, and although erected simultaneously are different in many respects. In the first place, the type of coal chute used requires a different track arrangement, that at Beacon Park having a trestle type with pockets on the sides and the other two designs having hoppers supported by a steel structure and spanning several tracks. It will be noticed that in each case there are four tracks coming to the turntable from the cinder pit, with the exception of West Springfield, where future plans make it inadvisable. Two of these tracks are for incoming and two for outgoing locomotives. This gives ample provision when cross-overs are provided for separating any locomotive out of a bunch and getting it to the house ahead of others.

Other features of the layout are evident in the illustrations and while these arrangements may not be ideal they are well suited to the conditions at the various points mentioned. Beacon Park at present handles 107 locomotives per day, West Springfield 101 and Rensselaer 47.

Turntables.

The very general and increasing introduction of the Mallet articulated compound locomotives makes the proper length of the turntable a matter of considerable importance. Where the articulated locomotives are to be used in road service it will, of course, be necessary to turn them the same as other locomotives and while 100 ft. has up to very recently been considered the maximum length for a turntable this will have to be increased when locomotives with over 90 ft. total wheel base, such as have recently been built, are to be handled. It is practically impossible to say that the articulated compound engines will not be used at any given point inside the next ten years and it is advisable to give this possibility full weight in deciding upon the size of the turntable.

That turntables should be power driven in all cases is not disputed, and with the successful arrangements, employing gaso-

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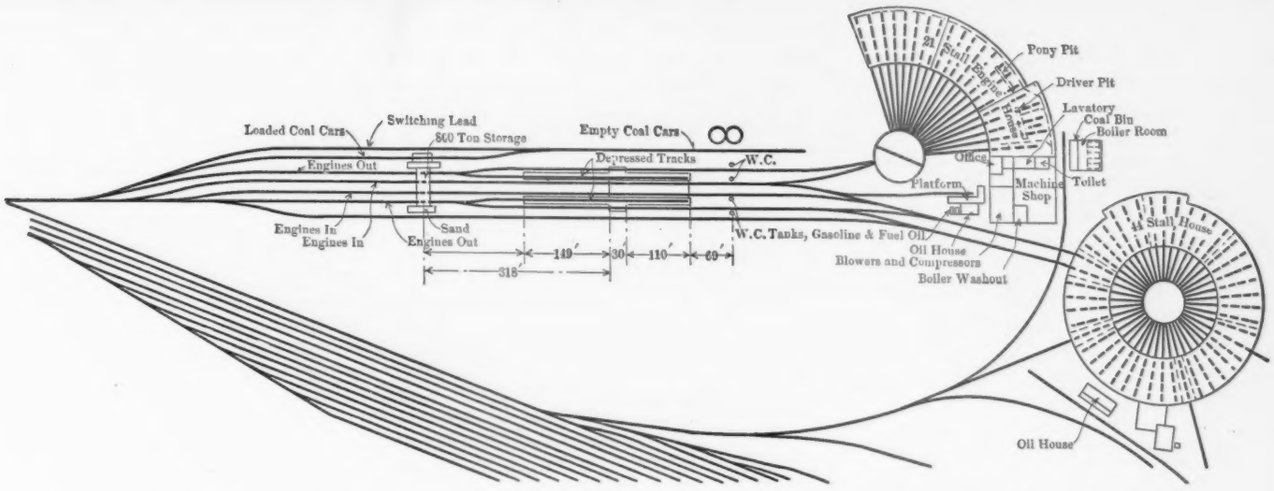
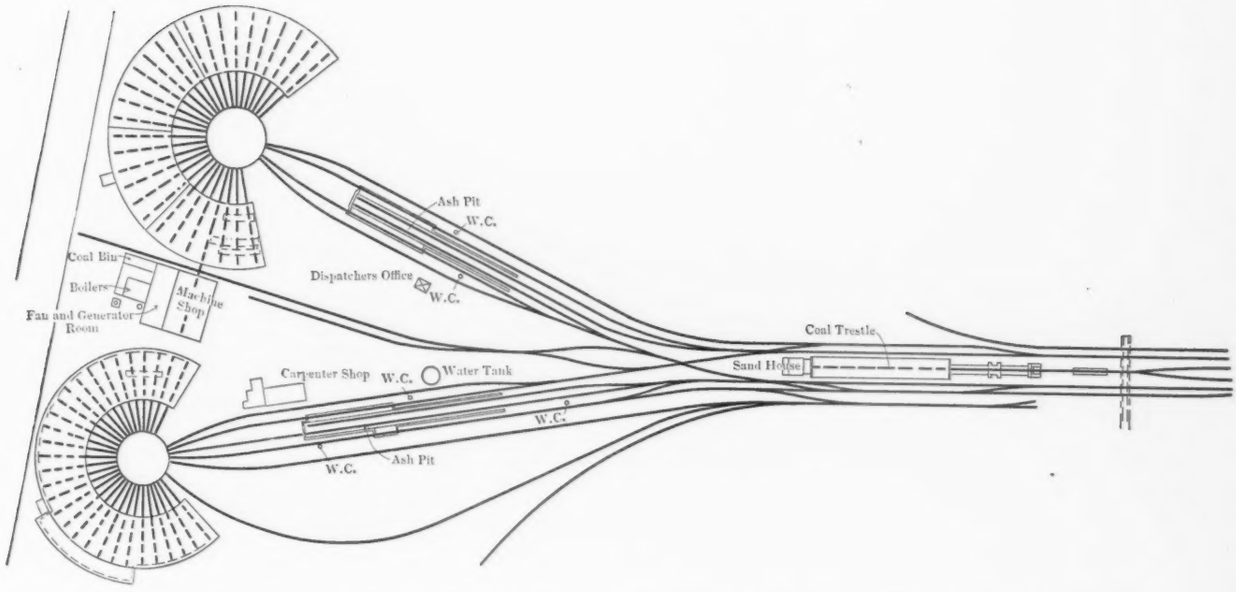
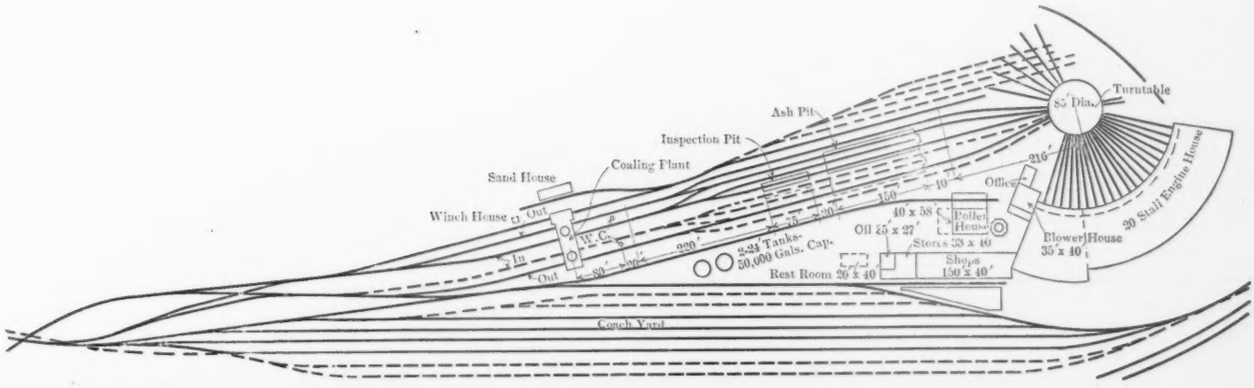


TRACK AND BUILDING PLAN OF THE WEST SPRINGFIELD LOCOMOTIVE TERMINAL OF THE BOSTON AND ALBANY RAILROAD.



TRACK AND BUILDING PLAN OF THE BEACON PARK LOCOMOTIVE TERMINAL OF THE BOSTON AND ALBANY RAILROAD.



TRACK AND BUILDING PLAN OF THE RENSSELAER LOCOMOTIVE TERMINAL OF THE BOSTON AND ALBANY RAILROAD.

line engines or electric motors, now in use, which may be applied to either old or new tables, it is unnecessary to give this question any discussion. The advisability of having two separate sources of power for operating the table, as, for instance, a gasoline engine on one end and an electric motor on the other, the latter to be used normally, is worthy of consideration. As most roundhouses are now provided with electric current it is considered profitable to use the electric motor on the turntables at such places; but with the forces organized to work with a power driven table all care should be taken to prevent its failure and, because of the difficult conditions, more or less unskilled handling and the possibility of accidents, it is considered wise at some points to install an emergency source of power. The electric circuit leading to the turntable motor should always be underground and the contact at the center pin should be well protected. A duplicate circuit leading to this motor from the source of power is advisable if the wires are exposed at any point. These circuits should never be put on top of the buildings where they would be subject to injury from wind or fire.

Locks should always be installed on the turntable, and it is well to have them connected with a signal light located on the table. It is also important to have the tracks line up with the table at both ends.

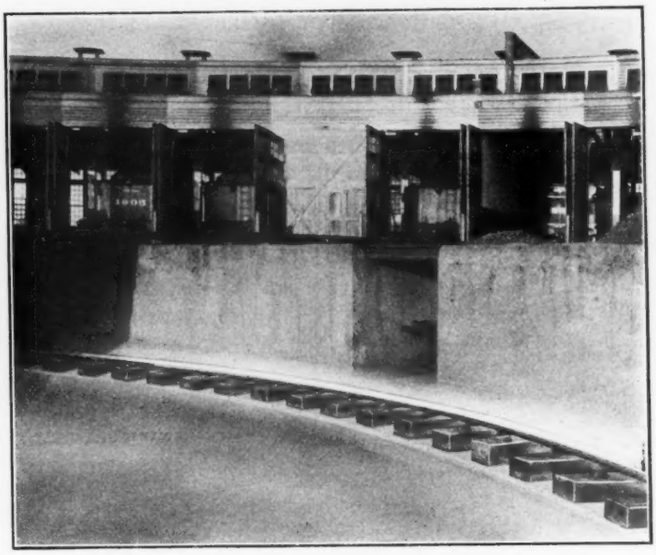
One of the illustrations shows a turntable pit which is practically ideal in climates where there is much snow or cold weather. The floor is of concrete and drains to a large outlet. The walls are also of concrete of ample thickness to retain their position and prevent cracking and are reinforced along the top by two circles of inverted rails, which are set flush with the top of the wall and give a bearing and fastening for the ends of the track rails. This distributes the blow over the concrete and prevents crushing at the rails. A 10-inch wooden cap is sometimes successfully used for the same purpose. A particularly noticeable feature of the pit illustrated is the arrangement of that part of the floor outside of the circle rail from the side wall to the top of the rail, so that it is not possible for snow or ice or any débris to collect outside of the circle rail. Short wooden or steel ties make a satisfactory support for the circle rail. A recess formed in the outer wall and covered over at the top forms a very handy place to store large wrenches, jacks or other tools usually found lying on top of the table or in the bottom of the pit and makes it possible to examine or repair the trucks on the ends of the table. A horizontal extension of the foundation of the circle rail on diametrically oppposite sides of the pit, for a short distance inward, will be found very useful when it is necessary to jack up the table. Tar concrete is sometimes used for a pit floor, as it has great elasticity and will not crack easily from heaving of the soil below.

At points where the snow fall is large a spiral arrangement of 2-in. pipe having six or seven turns, in the bottom of the pit and connected to the steam supply, will be found to be of great advantage. When this is installed, arrangement is made to close the drain leading from the pit and steam being turned into this pipe, the lower end is opened sufficiently to cause a good circulation; all of the snow in the pit is melted, forming a pool of warm water, into which the snow from the table and the circle inside of the house can be quickly shoveled and melted. When the pit is half full of warm water the drain can be opened and the water discharged.

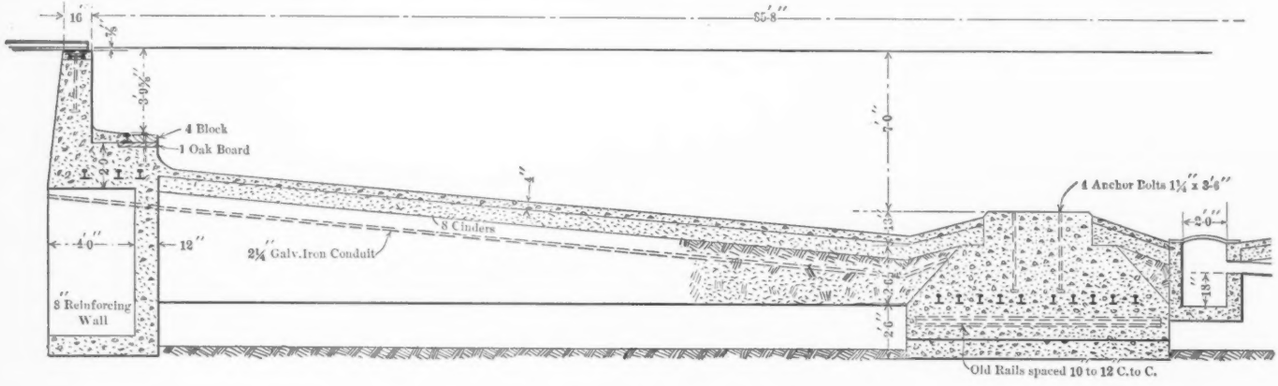
Roundhouse Structure.

The number of stalls or pits required at any point is easily arrived at by determining the proportion of the total time that the locomotives, which are to be handled, are in the hands of the mechanical department. Under normal conditions on most roads this should not exceed 25 per cent., and the number of pits required, assuming that all locomotives are to be taken care of inside of the engine house, is equal to 25 per cent. of the total number assigned to the division. This allows an average of six hours per locomotive on each pit, if it is assumed that all of the engines on a division are turned during 24 hours. The average detention, however, should not be more than three hours, leaving ample leaway for a sudden rush of power into the house if arrangements are made for storing engines ready for service outside of the house, which can be done without any detriment to the power and with little expense. The amount of repair work done at each particular point also influences the number of pits, and it may be advisable to add on three or four extra pits, forming, in effect, a shop to be used entirely for repair work. An example of an arrangement of this kind is seen in the East Buffalo engine house of the New York Central Lines, which was fully illustrated and described in the January, 1909, issue of this journal.

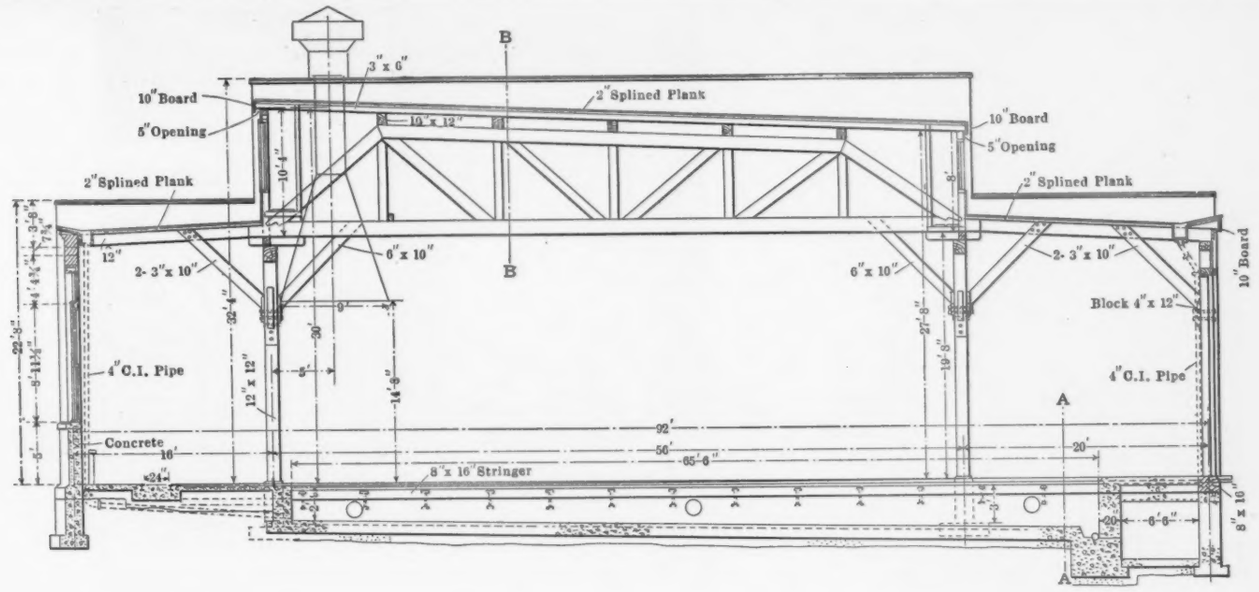
There are practically but two materials now being used for

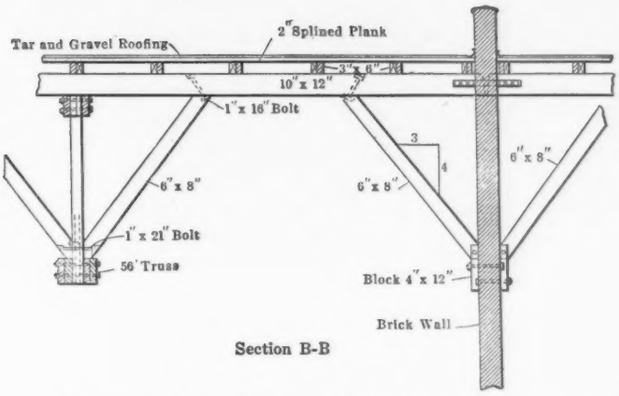


VIEW OF TURNTABLE PIT AT WEST SPRINGFIELD TERMINAL—B. & A. R. R.

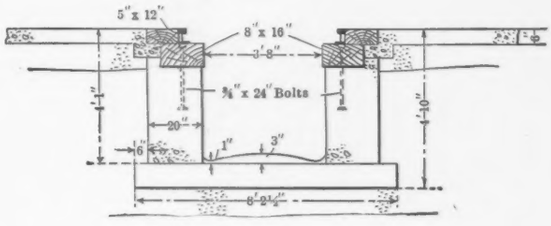


SECTION OF TURNTABLE PIT USED ON THE BOSTON & ALBANY RAILROAD.



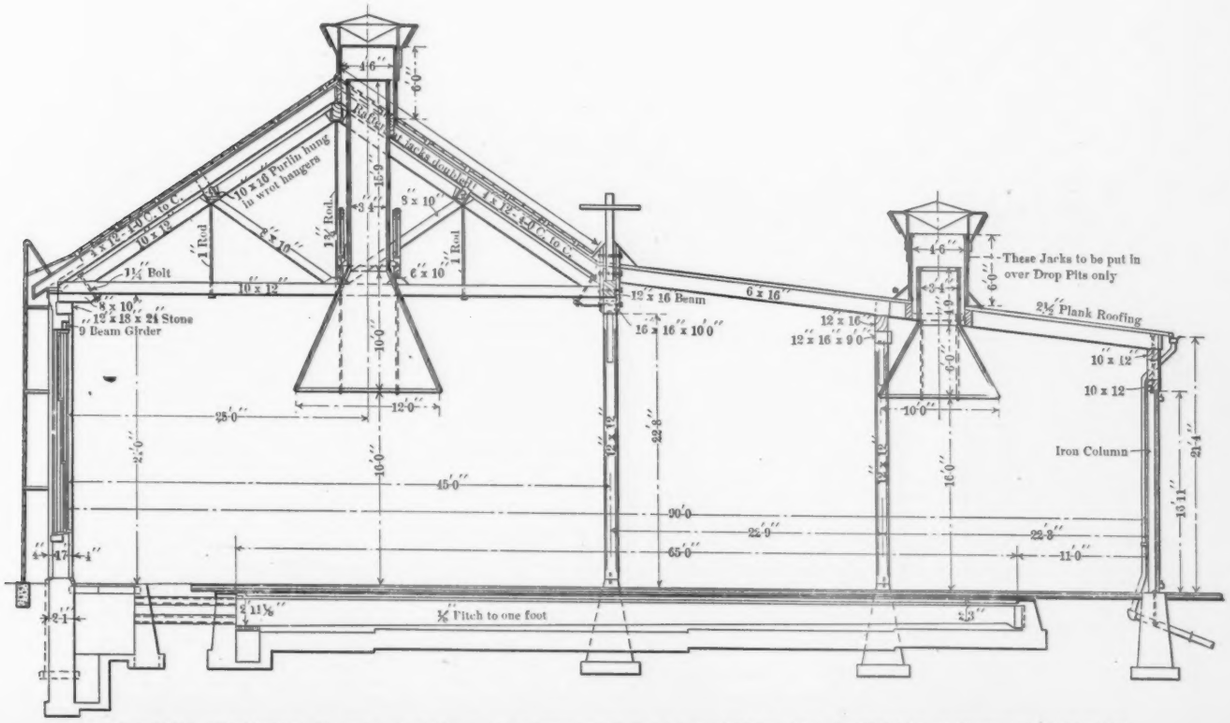


Section B-B

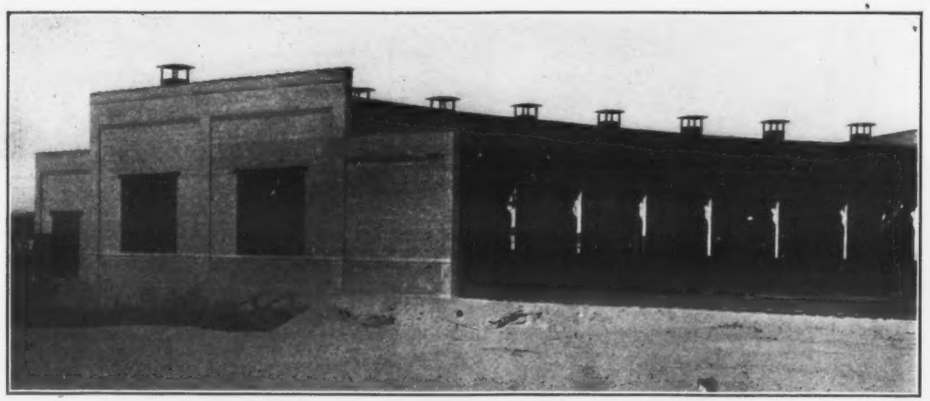


Section A-A

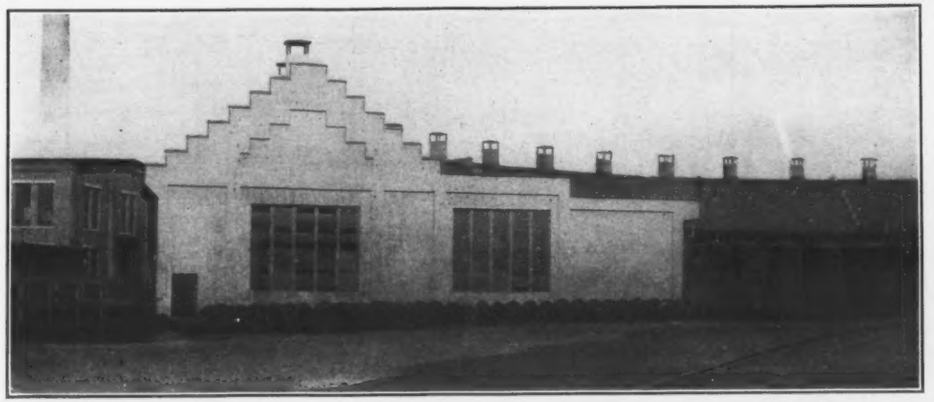
SECTIONAL ELEVATIONS OF THE 1908 STANDARD ENGINE HOUSE OF THE NEW YORK CENTRAL LINES AS ERECTED AT WEST SPRINGFIELD, MASS. THE 1909 STANDARD DIFFERS FROM THIS ONLY IN DETAILS.



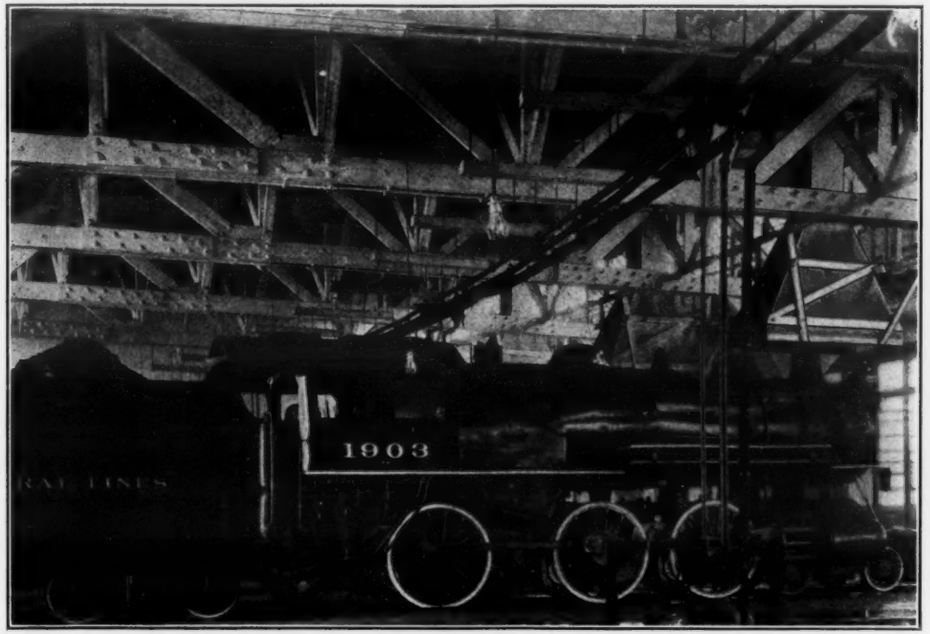
SECTIONAL ELEVATION OF THE ASHTABULA ENGINE HOUSE—LAKE SHORE AND MICHIGAN SOUTHERN RAILWAY.



VIEW OF THE WEST SPRINGFIELD ENGINE HOUSE.



VIEW OF THE BEACON PARK ENGINE HOUSE.



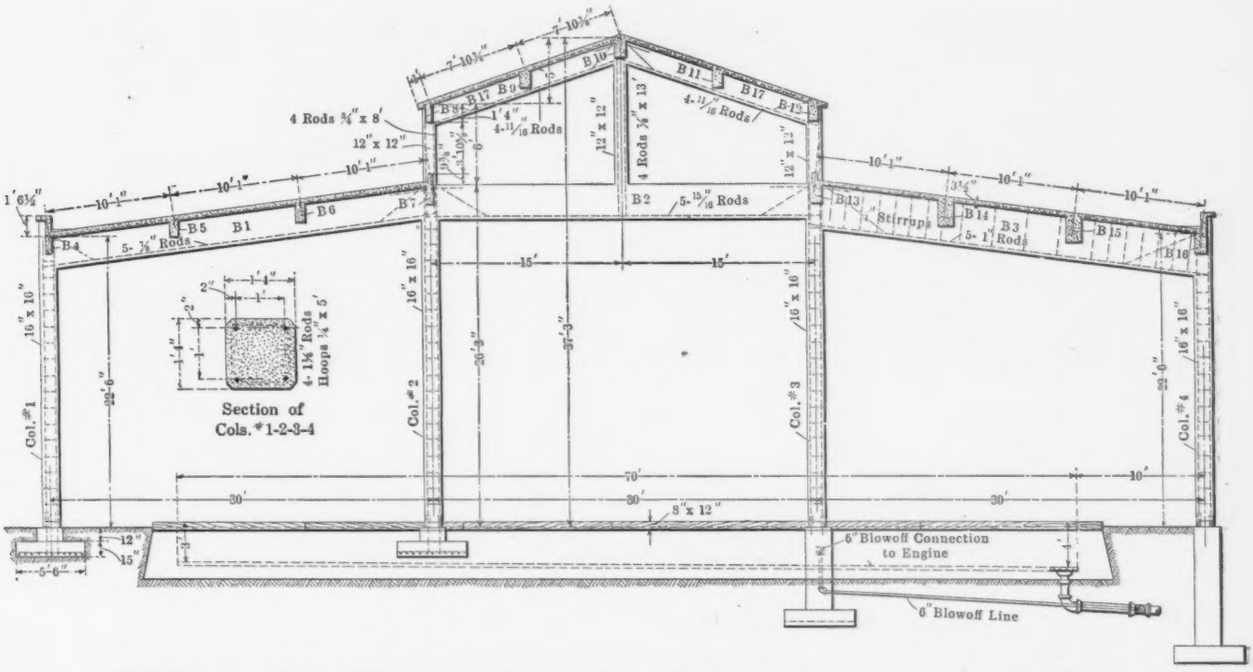
INTERIOR OF THE WEST SPRINGFIELD ENGINE HOUSE, SHOWING ROOF TRUSSES, SMOKE JACKS AND GOOD NATURAL LIGHTING.

INTERIOR OF THE DROP PIT SECTION OF THE WEST SPRINGFIELD ENGINE HOUSE, SHOWING DOUBLE SMOKE JACKS.

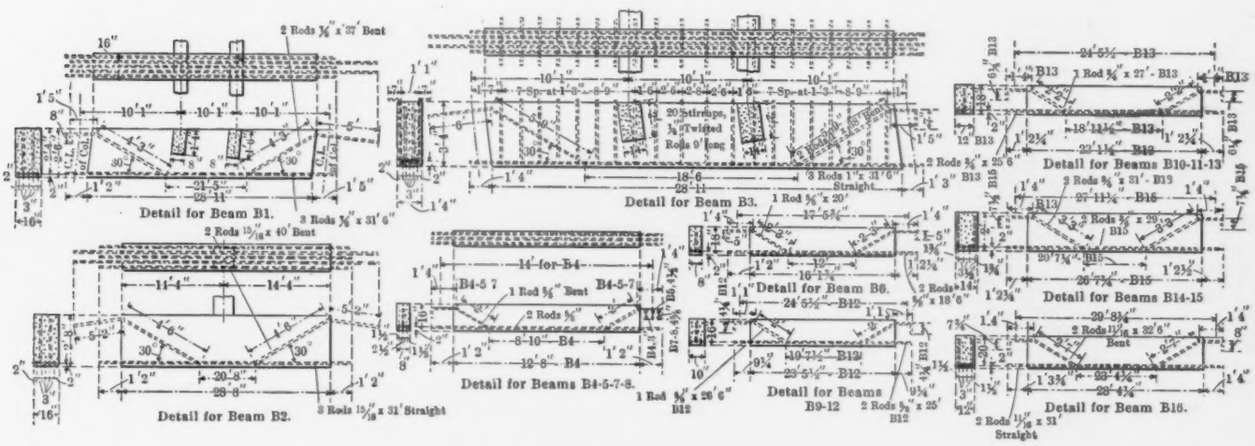
the walls of engine houses, viz., brick and concrete. The roofs are usually of wooden construction, but in a number of cases reinforced concrete is being tried and a few houses have steel roof trusses. It is possible to have a combination of the three principal materials, which has a number of excellent features. For example, there might be concrete pilasters in the outer circle, wooden roof structure and a brick filling below and above the windows in the outer circle, the lintels being made of I-beam set into the concrete posts. One advantage of an arrangement of this kind is the fact that when an engine goes through the wall of a house, as occasionally happens in spite of all precautions, the expense of repairs is comparatively small, whereas if the outer wall is of concrete, the damage is likely to be considerable, as is also the case where it is all of brick.

Reinforced concrete seems to have many features of advantage as a material for engine house structures, but no examples have been in service a sufficient length of time to determine its disadvantages accurately. Among recent examples of houses built exclusively of this material is a small house on the Lehigh Valley at Tifft Farm near Buffalo and a house on the Union Railroad at Oak Hill near Pittsburgh. The latter structure is shown in the illustrations. It is also being tried out at a number of other points throughout the country. Wood, however, still forms the most popular material for roof construction in an engine house and has much in its favor. The three engine houses on the Boston & Albany, mentioned above, have a wooden roof structure arranged in two different designs, as has also the engine house at Ashtabula on the Lake Shore & Michigan Southern Railway. Steel roof trusses have been successfully used at a number of points, but require very close attention to prevent rapid deterioration.

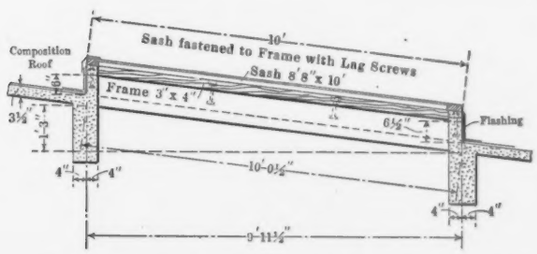
For economy in heating it is advisable to have the volume of air in the house as small as possible, which means that the roof should be flat and set low. For good ventilation, however, which



SECTIONAL ELEVATION OF THE REINFORCED CONCRETE ENGINE HOUSE OF THE UNION RAILROAD AT OAK HILL, PA.


Detail for Beam B1.
Detail for Beam B2.
Detail for Beam B3.
Detail for Beams B4-5-7-8.
Detail for Beam B6.
Detail for Beams B9-12
Detail for Beams B10-11-13
Detail for Beams B14-15
Detail for Beam B16.

BEAM DETAILS OF THE OAK HILL ENGINE HOUSE.



SECTION THROUGH SKYLIGHT OF THE OAK HILL ENGINE HOUSE.

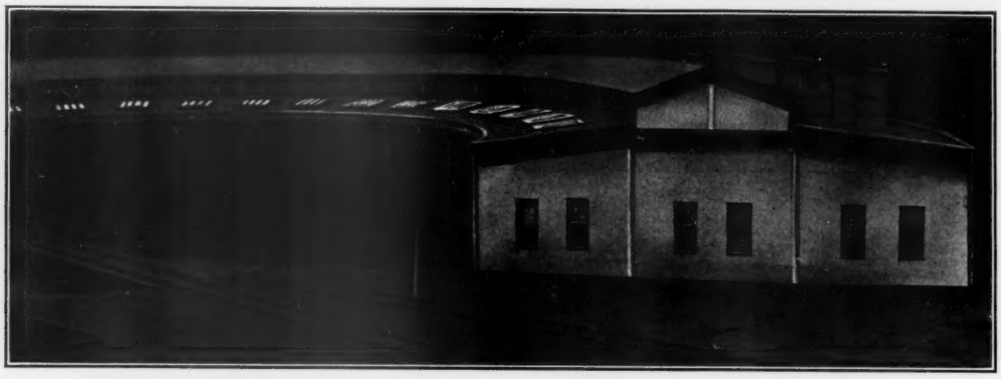
is fully as important as heating, it is advisable to have either considerable pitch to the roof with openings at the proper points, or a large monitor with windows at the sides.

For good lighting it is necessary to have either a roof which permits lighting in the center of the house or to have high walls giving large light area on the inner and outer circles. The lighting and ventilating consideration will overcome the heating feature at a majority of places and the type of house built at West Springfield and at Ashtabula, in both of which all of these features were given most careful study, illustrate two successful methods of obtaining good light and ventilation without an excessive increase of volume and consequent difficulty in heating. In the West Springfield design there is a 5-in. opening underneath the eaves of the monitor around the roof which permits a circulation of air into and out of this part of the house and rapidly carries away the steam and gases that naturally collect at this highest point. The purlins are laid parallel to the direction of the air currents, greatly assisting the free and rapid movement of the air. When the weather permits, opening of the windows still further assists in the discharge of the fumes. This type of structure gives an exceedingly well distributed light area, and, as may be seen in the interior view, there are practically no dark places anywhere in the house.

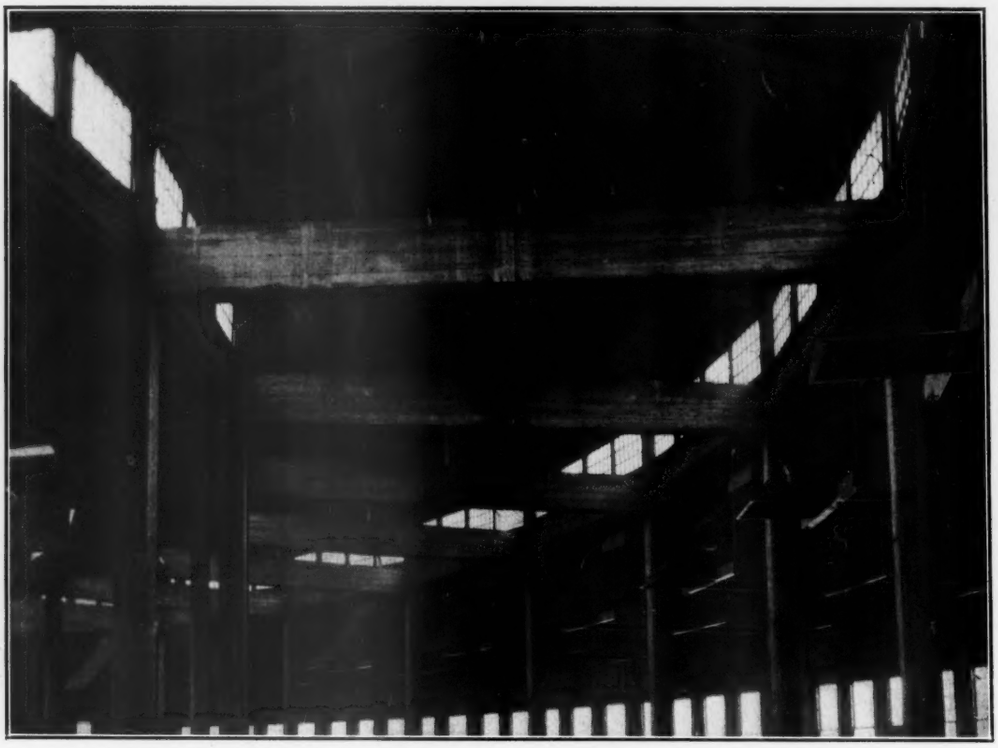
Since the interior of an engine house, especially at the top, is usually at a fairly warm temperature, it is not necessary to have a decided pitch to the roof for the purpose of preventing a heavy load of snow in cold climates, and it is necessary only to give sufficient pitch for drainage. In this connection it might be mentioned that it is very desirable not to have the roof drain into the inner circle and if the form decided upon slopes that way, the eaves should be pitched backward so as to make the gutter come just inside the doors and drain through pipes inside of the house. This will prevent the collection of ice along the inner circle, which is otherwise unavoidable in cold weather. A steam pipe running along the roof with connections extending down below the level of the roof into each gutter pipe has been found very useful for thawing out frozen drain pipes, but is of value only where the drain pipes are inside of the house.

Most of the good prepared roofings have proved to be satisfactory for covering roundhouses and are now very generally used.

The proper distance between the walls is subject to the same



GENERAL VIEW OF THE REINFORCED CONCRETE ENGINE HOUSE AT OAK HILL—UNION RAILROAD.



INTERIOR OF OAK HILL ENGINE HOUSE SHOWING ROOF BEAMS AND SMOKE JACKS.

considerations that were mentioned in connection with the length of the turntable and, as a rule, this dimension should be about 10 ft. greater than the length of the table. Some of the recently designed engine houses have a distance inside of 92 ft., which is ample for the present designs of locomotives, with the exception of the articulated type, but when it is considered that locomotives are now built which are 108 ft. 8 in. in length over engine and tender and 98 ft. 5⅛ in. total wheel base, it will be seen that the same difficulties encountered on the introduction of the Pacific type passenger locomotives are likely to again occur. It is probable that the articulated locomotive will be more or less generally used on all roads during the next ten years, and this fact should be given full weight in deciding upon this important dimension. The length of pits is, of course, determined by the same factors, and should be long enough to permit convenient

INTERIOR OF THE OAK HILL ENGINE HOUSE SHOWING SKYLIGHTS. (FLAT SKYLIGHTS ARE NOT USUALLY TO BE RECOMMENDED.)

entrance into the pit from one end or the other when the locomotive is under the smoke jack.

The conclusions of the committee on buildings of the American Railway Engineering and Maintenance of Way Association on this subject are as follows:

Reinforced Concrete Roofs for Roundhouses.—The conclusions as adopted were as follows:

(1) Reinforced concrete should be used below the floor when it is cheaper than plain concrete.

(2) The additional security against interruption to traffic from fire warrants the serious consideration of the construction of a roundhouse with a reinforced concrete roof.

(3) When the roof is of reinforced concrete the columns should be of the same material.

(4) Reinforced concrete should be used for the walls only where special conditions reduce its cost below that of brick or plain concrete and where plaster is not considered satisfactory.

Drop Pits.—Drop pits are, of course, a necessity in most engine houses, and there should be two sets on separate tracks, each to cover three pits, one being located and of a size suited for handling driving wheels and the other for truck wheels and tender trucks; the latter preferably being near the inner circle, so that the locomotive may be backed into place when it is necessary to drop the front truck. In the arrangement of drop pits it is advisable to so arrange the hydraulic jack and the movement of its carriage that it will not be necessary for men to be in the pit or below it when it is in operation. This has been done successfully in several cases by an air cylinder connected through sheaves to a cable or chain. A trolley hoist or jib crane covering the space between the tracks over a drop pit has been found of value for handling the removable sections of the floor, as well as driving boxes, eccentrics, etc. In some cases rails at gauge have been inserted in the floor of the house for a short distance on either side of the drop pit opening so that drivers taken out will not crush the floor.

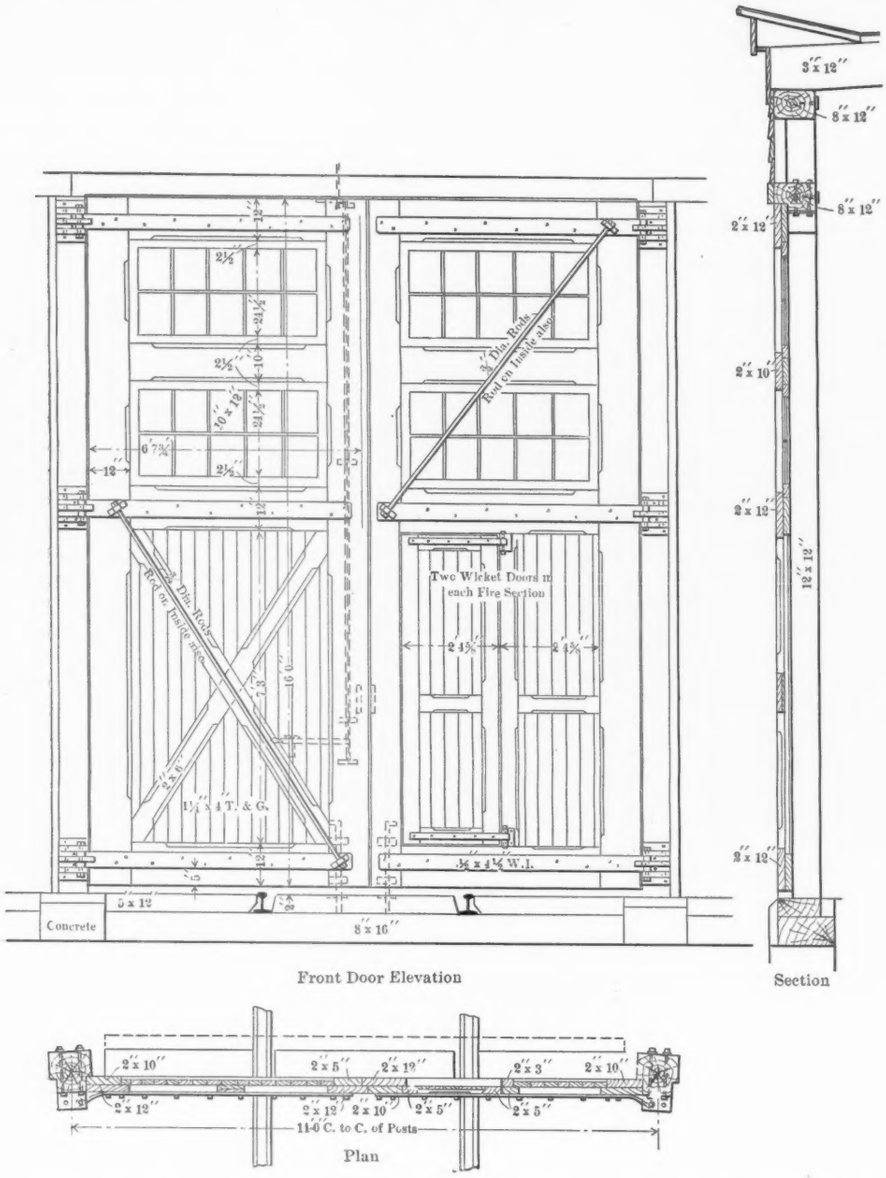
In the drop pit section of the house at West Springfield and a number of other points on the New York Central Lines, the outer wall is set back about 20 ft. and the drop pits are so located that it is not necessary for the tender to extend into the circle and the doors open while any wheels are being removed.

Fire Walls.—Fire walls of brick or concrete should be installed every seven or eight pits and be continued several feet above the roof. Openings fitted with automatic fire doors should be arranged at both the outer and inner circle. Fire walls are of advantage in cold climates for improving the average temperature and reducing drafts from open doors, as well as in case of fire. They also save fuel in a house not all of which is in use, as one or more sections can be closed off and not heated.

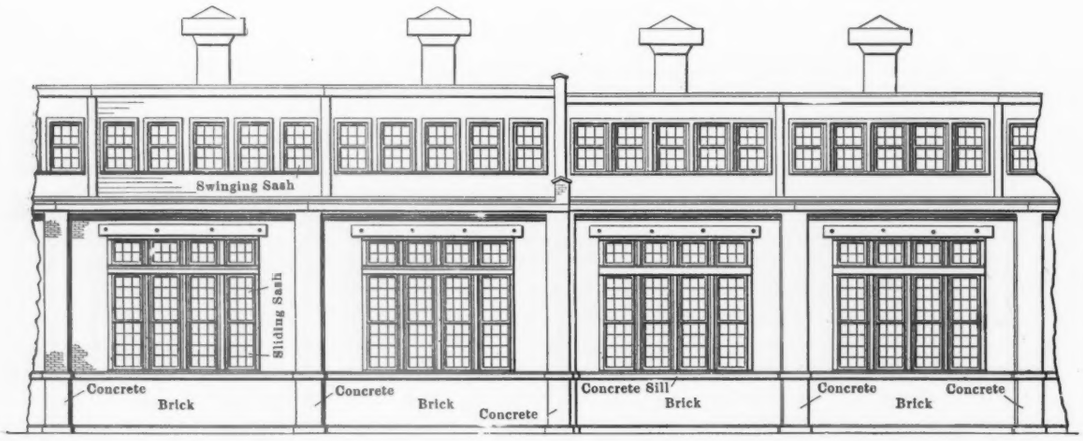
Floors.—After an engine house has been in service long enough to have all settlement of the foundations and of the filled in sections finished, a good concrete floor will probably prove to be the most satisfactory. Previous to that time, however, unless the ground below has not been disturbed, it is not advisable to install concrete, and paving bricks are very satisfactory for temporary use. In some cases creosoted wooden blocks set on a concrete foundation have been put in and proved to be most suitable. The floor should be as smooth as possible and well drained into the pits, so that it can be washed by using a hose at regular periods. The drainage feature is of importance also for keeping the floor dry, particularly along the sides of the pit where it is necessary for men to kneel down and where flexible electric cables will be lying around when men are working underneath the locomotive.

Good natural lighting has been mentioned above several times as being one of the most important features leading to a high efficiency in engine house work. In any, except very cold climates, the outer wall of a roundhouse should be very largely given up to lighting area, and in some of the most successful of the recently constructed houses, particularly the ones at Ashtabula and West Springfield, there is but little more than a pilaster for holding the roof trusses, between the window frames. The sill is brought to within about 5 ft. of the floor and the lintel is quite close to the eaves. On the inner circle the upper half of the doors should be given up to lighting and, if possible, a row of windows should be installed above the door frames. In this case the sash should be stationary, but for the windows in the outer circle there should be a movable sash for improving the ventilation during hot weather. Both the sliding and the swinging sash have proven satisfactory, the latter being preferably equipped with an operating gear, which can be reached from the floor. The sliding sash has an advantage for convenience in cleaning; but this feature can be well taken care of in the case of a swinging sash by a special brush, which will be described later. The latter arrangement has the advantage of giving a larger opening for ventilation and preventing direct drafts, but so far no operating device that is satisfactory in every way has been found. There are, of course, a number of arrangements that will operate the sash more or less perfectly, but the corrosive action of the gases soon coats the iron or steel parts with rust and soot and causes failure. The panes of glass should in all cases be small and the sash of very strong construction. Where windows are installed on the roof they should in all cases be vertical.

Doors.—Engine house doors have been the subject of considerable study during the past four or five years, and a number of designs have been elaborated, each answering the purpose to good effect under different conditions. These include the cus-



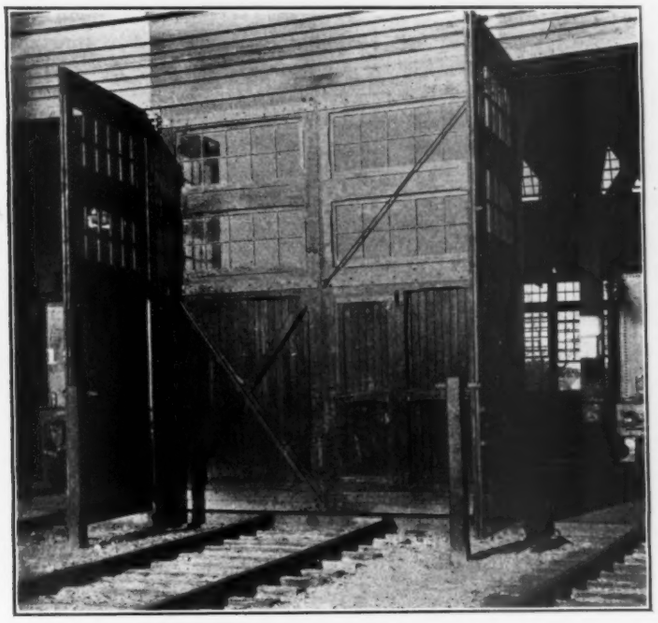
STANDARD 1908 ENGINE HOUSE DOOR OF THE NEW YORK CENTRAL LINES. THE 1909 STANDARD DOOR IS OF THE PITT BALANCED TYPE.



ELEVATION OF 1908 STANDARD ENGINE HOUSE OF THE NEW YORK CENTRAL LINES AS ERECTED AT WEST SPRINGFIELD.

tomary swinging door, the rolling lift steel or wooden shutter, the lifting door, which is lifted bodily, the Ritter folding lift door, and the Pitt balanced door.

In most cases the shape of the roof will influence the type of door to a considerable extent, especially where the lifting door is used, when the eaves on the inner circle must be at least 32 ft. above the rail level. If it is not possible to allow sufficient space between the top of the door and the eaves for good lighting area, it will be necessary to have the upper part of the door of glass, which eliminates the advisability of using the rolling lift door for this condition. The Ritter folding door has been found to



ENGINE HOUSE DOORS AT WEST SPRINGFIELD.

be very satisfactory for engine houses, as it can be used with a low roof, gives an opportunity for using windows in the upper section, and is quickly and easily opened.*

Taking everything into consideration, it is probable that for a majority of cases a swinging door of some type will be found the most suitable. They permit the installation of small doors without difficulty, can be made sufficiently strong to have a large area of glass, practically cannot become inoperative, and are the cheapest to install. The principal objection to the hinged door is found in the winter time in cold climates, where snow and ice may make it difficult to open and close, but if the roof is so designed that the eaves do not drain and form ice on the inner circle and the doors are properly designed and securely fastened, both closed and open, these disadvantages are overcome. One of the illustrations shows the 1908 standard New York Central hinged roundhouse door, which is of this type, and has proven as satisfactory as anything previously tried in places where heavy snow falls and cold weather are encountered.

During 1909, however, all of the new engine houses built on the New York Central & Hudson River Railroad have been equipped with a new type of door that seeems to have many special advantages for this use. It is called the Pitt balanced door, and has been in successful service in small sizes for a number of years. It is carried by a single roller carriage in the center of the top to which the connection of the door is pivoted. There is a roller guide at the top corner next to the post and two roller guides, one at the center and the other at the inner corner, at the bottom. In action, as the two doors are pushed outward at the center of the track, the edge of each door next to the post swings inward, being guided by the rollers top and bottom and at the same time the roller carriage moves toward the post until the door when full open is parallel with the track and half inside and half outside the house. The advantages of this arrangement are the same as those mentioned for a hinged door, and in addition it can be made considerably lighter than that type; it cannot be blown open; it opens and closes very easily, and when opened presents but half the usual area outside the house, requiring less than one-half the clearance and amount of snow cleaning in the circle.

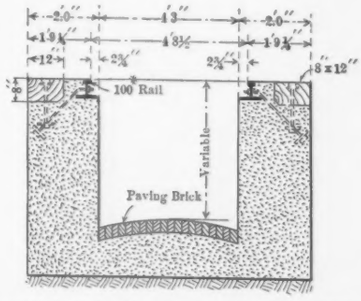
One of the greatest disadvantages found with hinged swinging doors in new engine houses is that the heaving of the track in winter interferes with their operation and the moisture from condensed steam in the interior swells them so that they bind at the top. There is also an opportunity for snow or dirt to get into the space between the door and its frame when it is open causing the hinges to be badly strained. These difficulties are provided against by leaving two or three inches clearance at the bottom, which can be closed by a slide working vertically and operated from inside and out, or by a long bag of sawdust, which can be thrown against it when it is closed in winter time. The top should be given good clearance when new to allow for swelling, the jamb being extended sufficiently to make a tight joint. The frame should be kept well away from the face and edge of the door, the joint being made by a weather strip. The floor should be extended beyond the outer face of the door for several inches and drop off abruptly.

Special attention should be given to the method of securing the doors in an open position, and probably the most satisfactory method is a heavy post, preferably set into a concrete foundation, which carries on its inner face a vertical angle iron forming a stop for two adjacent doors, each to be fastened open by a latch or bar secured to the post. This arrangement, when properly constructed, works very satisfactory.

For fastening the doors when closed, a locking device, which can be operated from both the inside and outside, should be used and so arranged as to catch before the doors are completely closed and draw them into position, pulling at the top.

The sash in an engine house door should be most substantial and the glass in small panes put in in a permanent manner to stand hard usage.

Pits.—In all of the later roundhouses the pits have been constructed of concrete, which, if of the proper mixture and properly put in, have proved to be very satisfactory. In some cases the bottom is lined with paving brick to prevent the breaking of the concrete by the fall of heavy parts. In all cases the pit should be so designed as to carry a jacking block at least 12 in. wide and set a sufficient distance from the rail so that the jack will rest upon it when under the bumper beam or tender underframe.



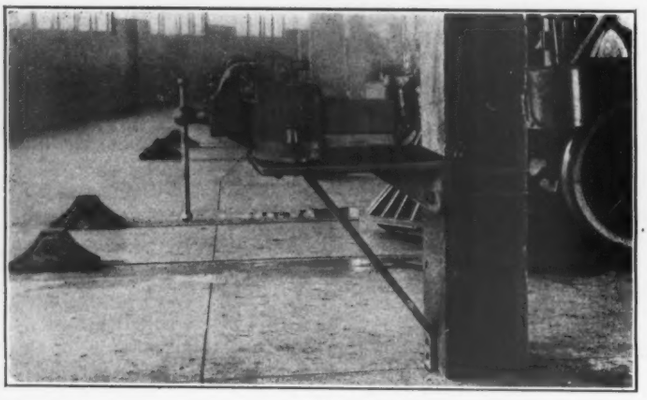
SECTION OF PROPERLY DESIGNED ENGINE PIT—UNION RAILROAD.

Where the jacking block is not supported by the pit wall it soon gets out of line and forms a low spot, in which water collects, making it very disagreeable for the workmen and unsatisfactory in every way. The illustration shows a cross section of a pit which is properly constructed in this respect, and is a satisfactory design. The drainage of course should be well taken off by a decided slope toward one end.

Stops.—Engine stops should be fitted to both rails of all tracks at a point where they will strike the front truck wheels when the stack is at the front end of the jack. Stops should be so designed as to offer the greatest resistance to the movement of the engine, but at the same time it is advisable to have them of such a height that they will clear the pilot. This, of course,

* See AMERICAN ENGINEER, January, 1909, p. 41.

means that they cannot be a sufficient height above the rail level to offer much resistance to the locomotive, and in a number of cases this difficulty has been overcome by depressing the track several inches just behind the stop, so that the pilot will pass over it and the front truck wheels drop into the depression against a stop 7 or 8 in. in height. In one of the illustrations stops will be seen which are excellent for their primary purpose, but which, in the case of an engine that could easily be stopped, will destroy the pilot before doing so. In some cases an emergency bumper is fitted close to the wall, but this is not usually considered necessary.



EFFICIENT ENGINE STOPS, BUT TOO HIGH TO CLEAR PILOT.

Heating.—In modern engine houses there are practically but two systems for heating, one being direct radiation from steam pipes and the other by hot air forced through conduits, usually opening into the pits. Both of these systems have their advocates, and both are proving satisfactory under very similar conditions at different points. In both cases the exhaust steam from the power plant is the principal source of heat, but live steam is required to supplement it in very cold weather. The hot air system has many advantages, among which might be enumerated its much more rapid drying qualities, its low cost of maintenance, the improved ventilation resulting from its use, and the control over its distribution. The principal objections that have been raised to it are the difficulty in providing enough heat, which means that the amount of radiating surface required has been underestimated. A hot air system should be of a size capable of renewing the entire volume of air in the engine house every 10 or 12 minutes and should be capable of maintaining a temperature of 60 degs. in the house on the coldest day. These requirements cannot be fulfilled without ample area in the main air duct and the branches. These must be very thoroughly drained or the efficiency will be very decidedly reduced.

Direct radiation from steam pipes is preferred by many master mechanics principally because it gives a higher temperature locally, which permits men to warm themselves, thaw out oil cans, etc., with greater facility. Beyond this it has no advantages that are not common to the hot air system, and it has the disadvantages of being more costly to maintain, of not directly improving the ventilation, and of being less rapid in drying out the machinery of a locomotive. When installed in the pits, heater pipes cause an increase in the fog in the house because of water dripping upon them and on account of the leaks which may occur at the joints. In such cases the pipes should be well protected by a ledge which will protect them from injury when heavy pieces are allowed to drop and also, to some extent, keep the water draining into the pits from striking them. In installing steam pipes around the outer circle they should never be continued across the wall opposite to the end of the pit where, in case of the locomotive getting away, they would be liable to tear down a very large part of that wall and possibly cause the fall of a section of the roof.

The conduits carrying the steam pipes, if such are used, both for the house supply and for heating, should have gratings, so that the radiation from the pipes will aid in keeping a comfortable temperature. In most cases where hot air heat is installed there are openings from the hot air duct several feet above the floor under the windows of the outer wall and between the pits on the inner wall, the former, however, not being directly in front of the pit. The openings into the pit should be as numerous as possible, and all openings from a hot air system should be fitted with dampers.

In considering this subject the Maintenance of Way Association adopted the following conclusions:

> Heating.—Conclusions: (1) Heat should be concentrated at pits. (2) General temperature of the engine house should be kept between 50 and 60 degs. (3) The best method for heating engine houses is by hot air driven by fans through permanent ducts (under the floor where practicable). The supply should be taken from the exterior of the building (no re-circulation should be allowed). The air should be delivered to the pits under the engine portion of the locomotive. Air to be heated as far as may be by exhaust steam, supplemented as required by live steam.

Lighting.—Electricity should be used for artificial lighting whenever possible and satisfactory conditions will be obtained by the installation of enclosed arc lights located between each two pits about one-third the width of the house from the outer circle and about 9 ft. from the floor. In addition there should be a 16 c.p. incandescent lamp between each two pits about one-third the width of the house from the inner circle and located about 10 ft. from the floor. Each arc light should have a separate cut-out. Over benches, around lockers, over entrances, doors, etc., lights should be located as conditions require. There should be at least two sockets for portable lights between each pit. The turntable circle should be lighted with at least two arc lights, neither one of which should be placed over the turntable. The yard lighting should, of course, be as extensive as possible, enclosed arc lights on moderately high poles being satisfactory if near enough together. Incandescent lamps hanging in the house should be protected by a heavy wire guard.

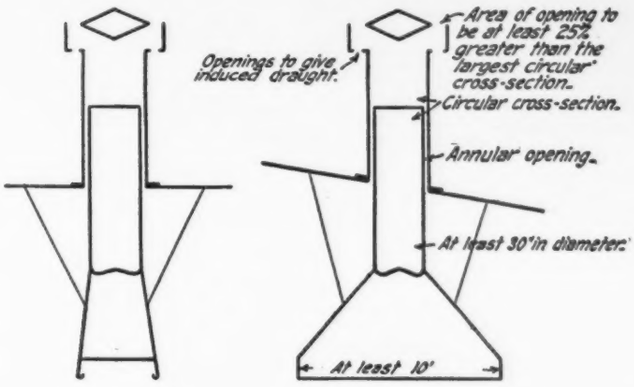
Smoke Jacks.—Many different materials have been tried and are being experimented with for smoke jacks. The conditions which the smoke jack has to encounter are of course exceedingly difficult, and so far no material has been found which is entirely satisfactory. Asbestos, both in plastic and board form, is being experimented with, and in a number of cases is reported to be satisfactory. At other points it is reported to be a failure. Wrought iron plates have been tried and if watched and carefully protected are a success. In the majority of cases, however, the wooden jack is being used, and with the smaller engines seems to answer the purpose fairly well, but is soon burned out by the larger locomotives. The jack should be designed to have a longitudinal opening at the bottom of about 14 ft., which will permit the engine being moved for valve setting without getting the stack from underneath the jack. The ends should have an angle sufficiently sharp to prevent any back draft when the stack is at the edge of the jack. The sides of the jack should extend 6 or 8 in. below the top of the stack, the ends, of course, being of a height to clear the highest stack, but can be fitted with flaps swinging in both directions, if desired. One of the illustrations shows a very satisfactory design of smoke jack, which is used at West Springfield, and another shows the double type of jack used in the same roundhouse in the drop pit section. It is desirable over pits having drop pits to have the jack sufficiently long to insure the stack being under it, no matter which driving wheel may be over the drop pit.

An annular opening of 4 or 5 in. should be left around the jack where it passes through the roof, for improving the ventilation. The jack itself should extend but a short distance above the roof line and the outer portion resting upon the roof will cover the opening, making an arrangement that will induce a draft from the house and pull the gases and smoke collecting under the roof up through this annular passage. The hood should be well designed to prevent any back drafts.

On this subject the conclusions given in the report of the Maintenance of Way Association at the 1909 convention are:

Ventilation.—This can best be accomplished by designing the roof so that "slope-up" is given to a continuous opening around the house and by the use of annular openings around the jacks. To obtain the full value of these continuous openings the purlins and rafters must be arranged so that they will guide the air currents up to the openings instead of obstructing them. The replacement of fresh air is most surely accomplished by hot air heating. Where no heating is needed, we believe that openings can be provided of such size that no mechanical ventilation will be required.

Smoke Removal.—Conclusions: Smoke removal should be separately provided for by the use of jacks, and the currents produced in the jacks should be utilized for aiding ventilation in the house by drawing air from the top of the house through annular openings leading into the top of the jack. Jacks should be without dampers, fixed and preferably built of non-corrosive material with cross-section not less than 30 in. in diameter. They should be of smooth material, circular in section above the hood, and extending well above the roof line; care in design should be taken to avoid any corners. The hood of a jack should have a minimum length of 10 ft.


Area of opening to be at least 25% greater than the "largest circular" cross-section.
Openings to give induced draught.
Circular cross-section.
Annular opening.
At least 30" in diameter.
At least 10'

so as to permit variation of location of an engine on the pit. The bottom of the jack should be as low as the engines served will allow, and it should be furnished with a drip trough; the slope upward should be gradual to the flue. The outline of recommended jack is shown in the illustration.

(TO BE CONTINUED.)

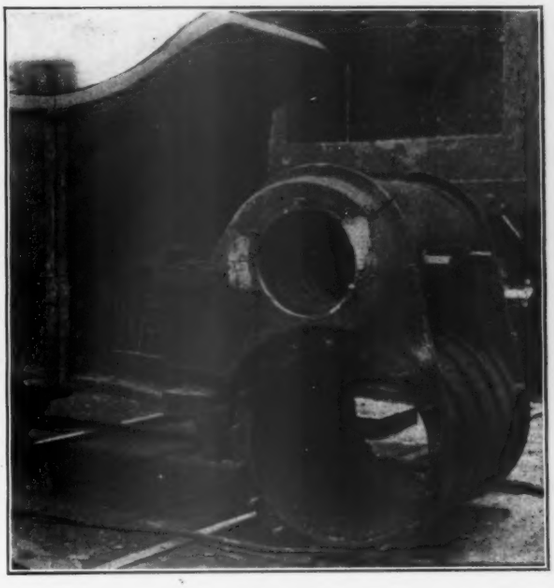
OXY-ACETYLENE WELDING.

CECIL LIGHTFOOT.

Among the many interesting applications of the oxy-acetylene welding process is the repair of shrinkage cracks, sand and blow-holes in castings, both of steel and iron. Successful repairs to large castings are now being undertaken that a few months ago would have been considered impossible.

An interesting repair was recently made on a locomotive casting. The photograph gives some idea of the size and nature of the work undertaken. This cylinder was found to have a small blow hole on the piston valve chest. The hole on being chipped out, so as to get down to sound metal, developed to a size of 4" x 2" x 2". In order to eliminate the chances of cracking likely to be caused by unequal expansion, due to the intense local heat of the blowpipe, it was first of all necessary to pre-heat the casting. This was done by an oil burner for a considerable area around the place to be welded, and was gradually brought to a red heat. The time taken in pre-heating was about three hours. The oxy-acetylene blowpipe was then brought into operation and the metal adjacent to the hole was brought to a molten state, when new metal was pressed in until the hole was completely filled up.

The actual time in welding was one and one-quarter hours. During this time the oil burner was left playing on the casting. After the weld was completed, the casting was kept hot by means of the oil burner for about an hour. The burner was then removed and the casting covered over with sheet asbestos so as to keep any draft off and allow the metal to cool off slowly.



REPAIR TO LOCOMOTIVE CYLINDER BY OXY-ACETYLENE WELDING PROCESS.

The cost of making these repairs, including pre-heating and labor, was approximately $7.

APPRENTICESHIP ON THE SANTA FE.

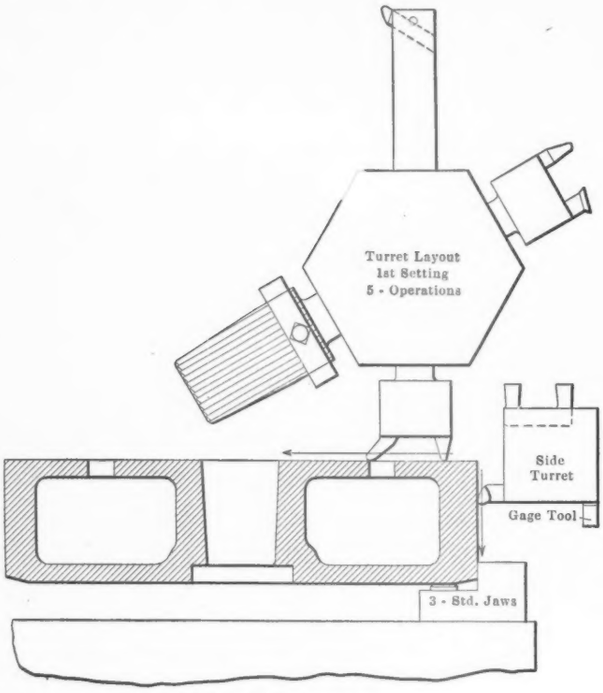
F. W. Thomas, supervisor of apprentices, has worked up a scheme whereby the apprentices at the smaller points will receive a modified form of instruction. Often there are only two or three boys at some of the smaller points, not enough to justify a regular instructor; these boys will be provided with the same appliances as are furnished the apprentices at the larger places, and they will be visited periodically by the nearest apprentice instructor and taught the same course that is now being taught in the regular apprentice schools. On December 1 all the apprentices on the system were receiving the benefits of the Santa Fe's liberal offer to assist them in mastering their chosen trades.

There are now established on the Santa Fe System schools as follows:

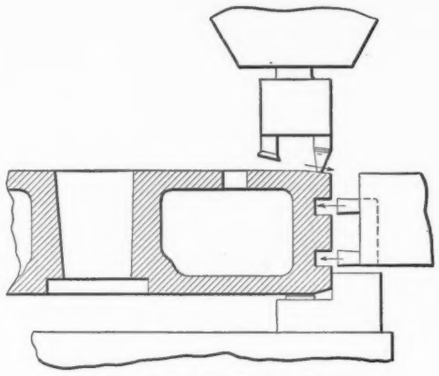
	APPRENTICES.		APPRENTICES.
Topeka	171	Clovis	15
Shopton	23	Albuquerque	38
Newton	19	San Bernardino	48
Arkansas City	7	Richmond	18
La Junta	23	Cleburne	56
Pueblo	4		
Raton	17	Total	439

—From the Santa Fe Employees Magazine.

PENSIONS ON THE ROCK ISLAND LINES.—It is announced that pensions will be paid on the Rock Island Lines beginning with January. Edward S. Moore, second assistant to the president, has forwarded blanks to all heads of departments asking for facts concerning officers and employees whose entire time has been given to this company's service and who have attained the age of 70 years or will attain it by June 30, 1910; also those who have been in continuous service 25 years or more and have become permanently incapacitated, regardless of age.



First Setting, First Operation.



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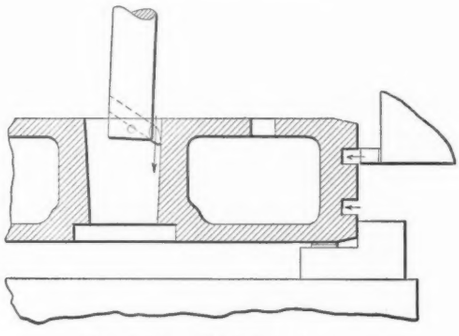

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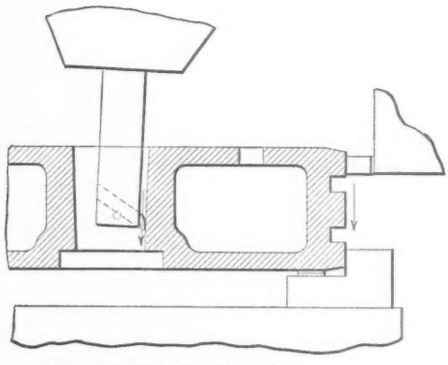
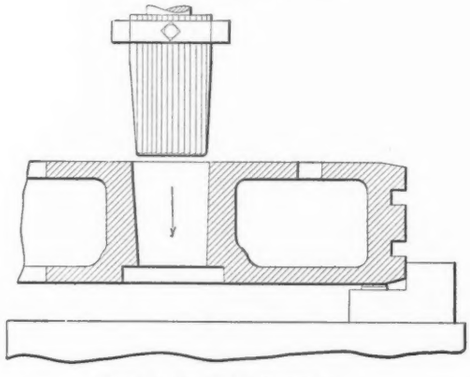
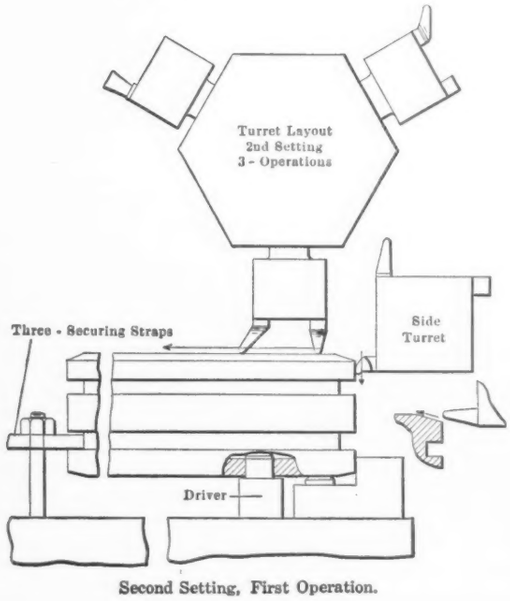


First Setting, Fourth Operation.



First Setting, Fifth Operation.



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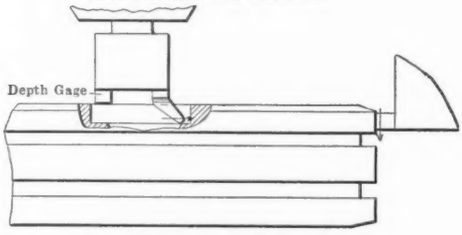
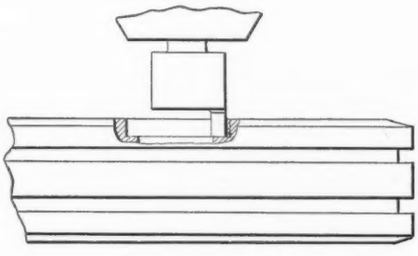


Second Setting, Second Operation.



Second Setting, Third Operation.

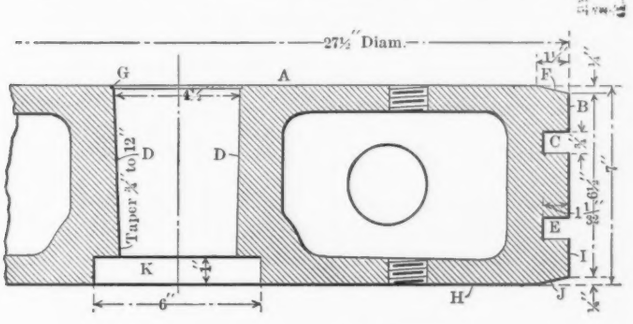
OPERATIONS REQUIRED FOR MACHINING A LOCOMOTIVE PISTON ON A VERTICAL TURRET LATHE.

OPERATIONS AND TIME REQUIRED FOR MACHINING A 27½-INCH PISTON ON A 36-INCH VERTICAL TURRET LATHE

	Item	Surface Machined	Operations	Depth of Cut	Feed per Rev.	Revs. per Min.	Minutes Each Operation	Minutes Required Actual
Setting No. 1	1		Chuck work				5	5
	2	A & B	Set tools for cuts A & B				3	3
		A	Two tools { 5¾" length of cut } Simultaneous cuts	3-16	1-12	6	13	13
		B	One tool .. { 5¾" length of cut } Simultaneous cuts	5-16	1-12	6	13	
	3	C & E	Set tools				1	1
		C & E	Two tools { Simultaneous cuts }		1-48	6	9	
	4	F	One tool, { Simultaneous cuts }	3-16	1-12	6	4	9
		F	Finish				3	
	5	D	Set tool				3	3
	6	C	Set tool and finish { These operations }	1-64	1/4	6	3	3
	7	E	" " " { were done while }	1-64	1/4	6	3	3
	8	B	Set tool and finish { boring D }	1-64	1/8	6	2½	2½
	9	D	Speed up and rough remainder of first rough cut, 3"	1-16	1-16	36	3	3
			Second rough cut	1-16	1-16		4	4
	10		Swivel head to zero				2	2
	11	D	Ream				2½	2½
	12	G					2	2
	13		Remove Piston				2	2
Setting No. 2	14		Chuck				5	5
	15	H	Set tools				2	2
		H	Two tools { Simultaneous cuts }	3-16	1-16	6	15	
		I	One tool, cut 1¾" long { Operations while cutting H. }	5-16	1-16	6	6	15
		J	Rough and finish cut 1¼" long { Operations while cutting H. }	3-16	1/8	6	4	
		I	Finish	1-64	1/2	6	2	2
		K	Rough face	1/4	1-24		2	2
		K	Bore	1/4	1-48		2	2
		K	Finish		Hand		1	1
			Remove				3	3
					Total time,		120	90

MACHINING A LOCOMOTIVE PISTON.

In his study of the number and kind of machine tools required in a locomotive machine shop in the April, 1909, issue of this journal, L. R. Pomeroy specified a 37-inch rapid production vertical turret lathe for boring and turning pistons. One of our readers has questioned the average time of two hours for doing this work, as specified by Mr. Pomeroy. Investigation has



PARTIAL SECTION OF PISTON.

proved that the time given was not only not too low, but that it may be accomplished in an average time less than this.

The accompanying table and illustrations show exactly how this work is being done in one large shop. This is not a *record* run, but represents results which may be gained by giving close attention to details and carefully planning the work. By using the vertical turret head and the side head at the same time it is possible to make a considerable saving in the time required for doing the job, as is indicated by a comparison of the totals of the last two columns of the table. This work was done on a 36-inch Bullard vertical turret lathe.

THE UNIVERSITIES AND INDUSTRIAL EDUCATION.

Charles Van Hise, president of the University of Wisconsin, briefly explained the extension work which is being done by that university in an address on "University Aid in Industrial Education" before the recent convention of the National Society for the Promotion of Industrial Education at Milwaukee, Wis.

"The rapid advance of applied knowledge in the world, and the absence of trade schools in the United States, have made it advisable for universities to give aid in industrial education. This has been done at the University of Wisconsin and to a lesser extent at other universities, by the establishment of the extension divisions. The extension division of Wisconsin, besides giving information by lectures and by institutes, as, for instance, bakers' institutes, gives systematic instruction by correspondence in many industrial lines. In this matter the correspondence schools, established upon a commercial basis, have led the way and performed a great service. The chief defects of such schools have been that each man must work by himself and that he does not come in contact with his teacher. The inevitable consequence is that comparatively few men have the stamina to continue long in study. The great majority drop out of the courses which they begin. Realizing these defects the University of Wisconsin has handled its correspondence work for artisans so that groups of men work together and meet a teacher, the traveling professor. This could only be successful by the cordial co-operation of the manufacturers. The manufacturers, and especially those in Milwaukee, have furnished class rooms in which the men may meet; not only this, but they pay their men for the time they are receiving instruction, an hour once a fortnight.

"This attitude upon the part of the manufacturer is broad gauged liberality, based upon a desire to help his men to improve themselves as well as to have the services of trained men.

"The traveling professor and the class room work place study by correspondence upon a new and higher plane. Under the new conditions the great majority of students persist to the end of their courses. The work of the Wisconsin extension division has met with enthusiastic support in this State and pending the wide development of the trade school it is the best method yet devised to give industrial education.

"Even when the trade school is fully developed, as it will be in the future, the extension work for artisans will be continued. Men need a broader training than a simply vocational one. They need to go farther than the trade school. When the trade schools are able in this State to do satisfactorily the vocational work demanded, it will be the aim of the University of Wisconsin to continue to teach the artisan after he leaves the trade school, not only in advanced studies relating to his vocation, but in studies which concern his duties as a citizen, and which concern him as a man. It is our desire to open to all the way to a higher intellectual and spiritual life."

FUEL ECONOMY ON TESTING PLANTS AND RAILROADS.*

H. H. VAUGHAN.

Most of us have at one time or other been confronted with the statement that there was a terrific waste in the operation of a steam engine, something like 5 per cent. of the heat developed by the coal burned under the boiler being all that was transformed into useful work. That such a statement is true is easily shown by comparing the coal consumption of an ordinary engine, taking say four pounds of coal per horse-power hour, and the work that is the equivalent of the heat in the coal. A horse power is 33,000 foot pounds of work per minute, so that a horse power hour is 1,980,000, or very nearly two million foot pounds of work. Four pounds of coal will develop about 60,000 b.t.u. of heat and as the mechanical equivalent of heat is 778 foot pounds per b.t.u., the total work that is the equivalent of the heat contained in the four pounds of coal is about forty-six million foot pounds. As only two million or under one-twentieth of this is developed as useful work, the statement that 95 per cent. is wasted is entirely true and cannot well be denied.

As is well known, the larger part of this 95 per cent. is not waste at all in the proper sense of the word, but is the necessary result of the natural laws governing the action of heat engines. We are very much in the position of trying to utilize sea water, pumped into a tower at Winnipeg, for power purposes. If the tower was 200 feet high and the discharge was into the river at a height of 750 feet above sea level, the best possible efficiency that could be obtained would be by using 200 feet out of the total head of 950 feet available, or about 21 per cent. The 79 per cent. that was lost on account of the impossibility of utilizing the total down to sea level would not be waste, but power rendered unavailable on account of the conditions under which it was supplied.

While not by any means an exact simile, such a case does to a certain extent resemble the conditions under which heat can be used in the heat engine. The heat that can possibly be utilized depends on the proportion of the range of temperature through which the engine works to the initial temperature, and the initial temperature, like the height of the water tower, is not measured from the level at which we can use it, but from the absolute zero of temperature, about 465 degrees below zero Fahrenheit. The most perfect form of heat engine therefore working between a temperature of 390 degrees, or that of steam at 200 pounds pressure, and 60 degrees, the temperature of the atmosphere, could then only have an efficiency of $\frac{330}{855}$ or 38 per cent. It is needless to say that nothing approaching this could practically be realized, not only because such extreme efficiency would be more expensive than the results would justify, but also because any such engine would have to be of a totally different type to the existing steam engine, which cannot work under the conditions demanded for the most economical heat engine. In order therefore to afford a practical working comparison, the definition of an ideal steam engine has been adopted, as follows:—

AN IDEAL STEAM ENGINE.

"A perfect engine receiving steam at its upper limit of pressure equal to that measured close to, but on the boiler side of the engine stop valve, and continuing this pressure and temperature up to cut-off. Beyond cut-off the steam is assumed to expand adiabatically in the cylinder down to a pressure equal to the back pressure against which the engine is working. The steam is then exhausted from the cylinder at constant pressure corresponding to the lower limit of temperature."

This definition, while it may appear rather complicated, really specifies a perfect steam engine, working as a steam engine does, with steam at boiler pressure and an exhaust pressure determined by conditions, but with perfect expansion and an entire absence of all the losses due to cylinder condensation, compression, and the various other causes which prevent an actual engine from obtaining the greatest possible economy. Such losses are, however, more or less avoidable, and it is the aim of the steam engineer to reduce them by compounding, superheating, and other means, so that the ideal engine thus set up may be fairly taken as a standard which may be approached, although never equaled, by an actual steam engine.

DEGREE TO WHICH THE LOCOMOTIVE HAS APPROXIMATED AN IDEAL ENGINE.

It is interesting to examine the degree to which the steam locomotive has so far approximated this ideal engine, and for the information in connection with steam locomotives we can use the results obtained in the tests conducted on the testing plant at the St. Louis Exposition in 1904. The conditions under which these engines worked may be taken as a boiler pressure of 200 pounds and an exhaust pressure of 6 pounds, and with these limits the ideal engine would require about 250 b.t.u. per horse power per minute, or 12.8 pounds of steam per hour at boiler pressure. The simple locomotives tested required from 23.6 to 28.9 pounds, while the compounds required from 19.0 to 27.0 pounds, so that compared to an ideal steam engine under the same conditions, the efficiency of the simples was 54 to 44 per cent., and of the compounds 67 to 47 per cent.

The ideal engine taking 250 b.t.u. per horse power per minute, or 15,000 b.t.u. per hour, has an efficiency of 17 per cent. This is obtained by multiplying 15,000 by 778, which gives the work, that is, the equivalent of that amount of heat, 11,670,000 foot pounds, and dividing this into 1,980,000, the foot pounds equal to the work of one horse power hour. As the engines on the testing plant may be said to have had an efficiency of about 50 per cent. for the simples, and 60 per cent. for the compounds, we see that the actual heat efficiency was from 8½ to 10 per cent., based on the total heat delivered to them in the steam, so that even in the case of these particular engines there is 90 to 91½ per cent. of the heat in the coal that cannot be used, that our friend the fireman cannot be blamed for.

BOILER EFFICIENCY.

The efficiency of the engine is, however, only one of the factors determining the proportion of the heat in the coal that can be developed as useful work. The boiler, while not limited by the same conditions as the engine, is still unable to deliver in the steam the full amount of heat that is generated by the coal burned. The losses are, however, nothing like as serious as those that take place in the conversion of the heat in the steam into work, and are only due to the combustion not being entirely perfect, the radiation of heat from the boiler, and to the heat contained in the gases that passes away into the stack. Under favorable conditions the sum of these losses may only amount to about 20 per cent., so that 80 per cent. of the heat developed by the fuel may be actually present in the steam delivered by the boiler. In locomotive practice, however, boilers are not worked under as favorable conditions as are stationary boilers, on account of the enormously larger amount of steam that has to be generated by a boiler of a given size. In place of evaporating 3 pounds of water per square foot of heating surface per hour and burning 15 pounds of coal per square foot of grate, as much as 16 to 18 lbs. of water are evaporated and 120 to 140 lbs. of coal burnt.

This increase in capacity, while necessary in order to obtain

* A paper presented before the November meeting of the Western Canada Railway Club.

the output from a locomotive boiler that would require a whole battery of stationary boilers, is only rendered possible by a sacrifice of economy, or in other words the efficiency of the locomotive boiler is generally considerably less than the 80 per cent. mentioned above. The reasons for this loss in efficiency in the boilers at the St. Louis Exposition were thoroughly investigated by Mr. Lawford H. Fry, and Fig. 1 shows one of the results of the calculations made by him which is exceedingly interesting. It is one of several which he presented in his paper on "Combustion in Locomotive Fireboxes" before the Institute of Mechanical Engineers,* and refers to the trial of the New York Central balanced compound engine No. 3000. The diagrams for the other engines are generally similar, with some exceptions that will be mentioned later.

The efficiency of the boiler, which is shown by the lowest line, is slightly over 70 per cent. when coal is burnt at the rate of 30

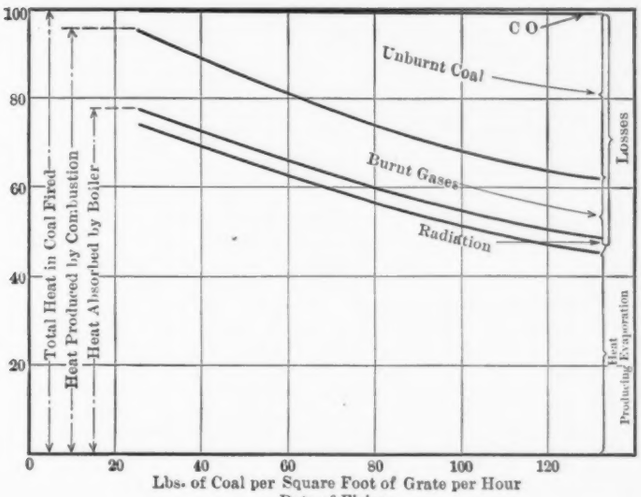


FIG. 1

pounds per square foot per hour, and is gradually reduced to about 46 per cent. as the rate is increased to 120 pounds per square foot per hour. The space between the lowest line and the next above it represents the heat radiated away by the boiler, so that this line shows the total heat absorbed by the boiler from the coal. The space above this represents the heat escaping in the hot gases passing out through the front end, while the space between the two upper lines is the loss from unburnt coal. The loss from imperfect combustion, or from the formation of carbon monoxide, is represented by the space between the highest line and the top of the diagram. This diagram is very interesting. In the first place it shows that at low rates of combustion the locomotive boiler is just as efficient as any, as the line showing the heat utilized would evidently be about 80 per cent. at a rate of 20 pounds per square foot per hour, and in the next place, the losses from imperfect combustion are exceedingly small. This loss was not, however, as small as this in all the engines tested, as in one of them it became about 16 per cent. at the maximum rate of combustion. This is thought to have been due to insufficient ashpan openings and it attracted general attention to that detail of the engine.

On most engines, however, this loss was small, and it is evident that from this cause, there need not be very much loss on a locomotive. It must be remembered that the firing at St. Louis was about as perfect as possible and the running conditions uniform, but from the fact that insufficient air causing a dull fire ran this loss up to 16 per cent. in place of 2 or 3 per cent., it is evident how easily a loss in efficiency may be caused by heavy or intermittent firing which does not keep the fire in a clean, bright condition. The heat wasted by the burnt gases is almost constant. This peculiar fact is due to the decreased amount of air per pound of coal required at the higher rates of combustion, which compensated for the increased temperature at which the gases passed into the front end. The same thing occurs in all the tests and shows how well the fires were kept free from holes and the grates properly and uniformly covered.

The important loss, which increases as the rate of combustion increases, is that from unburnt coal. This loss is not entirely explained. The larger part of it is accounted for by the sparks and coal pulled through the tubes and stack without being burnt, but this is not sufficient to account for the entire loss. The loss from sparks is known to be about 20 per cent. of the total coal burnt, at the highest rate of combustion, and the balance of the loss is accounted for in different ways. Mr. Fry considers a large portion of it is due to unconsumed hydrocarbons, but it is not definitely known whether this is really the correct explanation. It is possible that the line showing the heat loss from the burnt gases should be rather higher, which would decrease the loss shown as unburnt coal. There is also a loss due to good coal shaken down into the ashpan, but with the care taken in carrying out these tests, this also is comparatively small.

All we can say is that after the various known factors have been taken into account, that a portion of the loss due to unburned coal is from an undetermined cause, and that the explanation offered by Mr. Fry is possibly correct, namely, that it is due to unconsumed hydrocarbons passing away into the front end. He considered that this may be produced by the partial distillation of the particles of coal that are carried off the grate by the draft, or that there may be unconsumed free hydrogen in the flue gases. Evidence supporting this view is furnished by the fact that the gas analysis shows more nitrogen than can be accounted for by the other products of combustion, and that if this excess of nitrogen is assumed to be a hydrocarbon gas, the heat contained in it, together with the expected loss by sparks and a reasonable ashpan loss, make up very closely the total loss through unburnt coal. There is here possibly a chance for better economy, that we have hitherto not suspected, but it may be stated that so far as can be learned from the tests, it will not be obtained from the use of a brick arch as it was found that its value consisted in the reduction of the loss by imperfect combustion, due to the formation of carbon monoxide. The engine from which this diagram of heat balances was obtained was fitted with an arch and, as it shows, the loss from carbon monoxide was exceedingly small. On the engines not having a brick arch there was a considerable loss from this cause, amounting to as much as 16 per cent. at higher rates of combustion, and although it so happened that these same engines were subject in each case to unfavorable conditions, there is still good evidence to support the claim made that a properly proportioned brick arch will effect a saving in coal of 5 to 10 per cent.

EFFICIENCY OF THE LOCOMOTIVE AS A WHOLE ON THE TESTING PLANT.

These points, however, while interesting, do not affect the main information given by this diagram, which it may be stated, is from the most efficient boiler tested at St. Louis. It shows that, under the most perfect conditions of testing, uniform work, economical firing and a boiler in as good condition as possible, the heat accounted for in the steam is from 50 to 70 per cent. of the heat in the coal, as the rate at which the coal is burnt decreases from 110 to 40 pounds per square foot of grate per hour. If this efficiency is combined with that of the engine, which as previously stated varied from 8½ to 10 per cent., we find that the total efficiency of the locomotive, under testing plant conditions, varies from 4½ to 7 per cent., so that we see that the general statement of a loss of 95 per cent. of the heat present in the coal, is confirmed by the best results that have so far been obtained from locomotives.

We also see to what a large extent this loss is unavoidable as long as we are forced to transform heat into work by means of any form of steam engine, and the high degree of perfection that has already been reached by our present locomotives when the limiting efficiency which they could possibly attain is properly considered.

The figures so far discussed have entirely referred to efficiency on the basis of indicated horse power. Before this power reaches

* See AMERICAN ENGINEER, May, 1908, page 186.

the rail, it is reduced by the friction losses in the cylinders, motion and axles, and the resultant power is what is termed the dynamometer horse power. Figs. 2, 3 and 4, which are reproduced from the report of the St. Louis tests, show the coal per dynamometer horse power hour for three freight locomotives tested at St. Louis, at forty, eighty and one hundred and sixty revolutions per minute respectively. It will be seen that the most economical results were obtained from No. 585, a Michigan Central cross compound, which at low speeds showed a fuel consumption of only 2¼ pounds per horse power hour. This corresponds to a total efficiency of 7.5 per cent., and is an exceedingly economical result for any type of non-condensing steam engine. As shown on the diagrams the fuel consumption increased at higher speeds, and at 160 r.p.m., which corresponds to 30 miles an hour for a 63 in. wheel, it amounted to 3½ pounds. Fig. 5 shows roughly the coal consumption of these different engines as the speed increased, and is interesting when their varying types are considered.

No. 1499 is a Pennsylvania Railroad simple consolidation, 22 by 28 in. cylinders, 56 in. drivers, 205 lbs. boiler pressure, heating surface 2,844 sq. ft., grate area 49.2 sq. ft.

No. 734 is a Lake Shore & Michigan Southern simple consolidation, 21 by 30 in. cylinders, 63 in. drivers, 200 lbs. boiler pressure, heating surface 2,858 sq, ft., grate area 33.7 sq. ft.

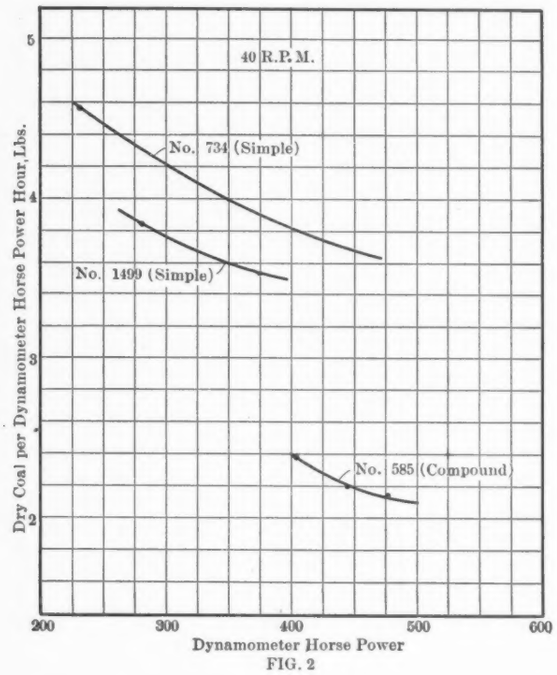


FIG. 2

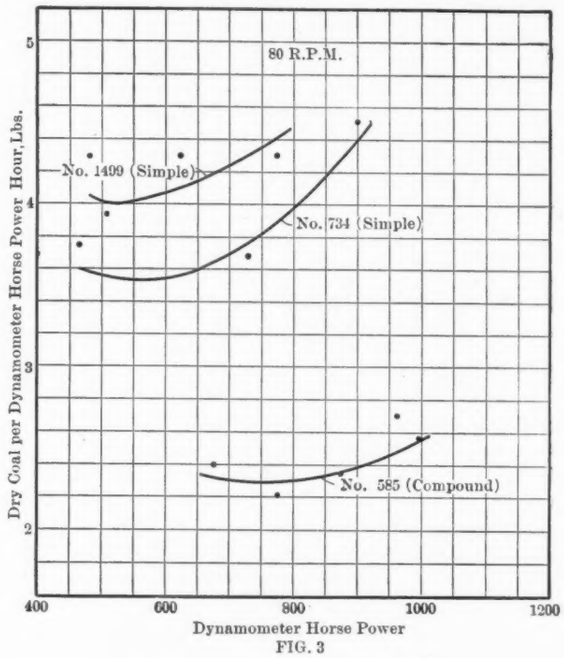


FIG. 3

No. 585 is a Michigan Central compound consolidation, 23 and 35 by 32 in. cylinders, 63 in. drivers, 210 lbs. boiler pressure, heating surface 3,181 sq. ft., grate area 49.4 sq, ft.

The compound engine is evidently far more economical than the simple, but it should be remembered that the conditions in a testing plant are more favorable to this type of engine than are those in regular road service. On the testing plant, they are working absolutely uniformly, everything is maintained as constant as possible during the time the test is conducted, and it is under these conditions, as we know, that the best results from a compound engine can be obtained. The boiler efficiency of No. 585 was also exceedingly good, and in fact a large proportion of the economy is due to this, as No. 734 showed only from 70 per cent. to 82 per cent. of the boiler efficiency of 585, and that of engine 1499 showed very poor results at the higher rates of evaporation, due to the insufficient air supply. Still while there may be reasons why the simple engines showed so much greater fuel consumption than the compound, there are no reasons why the compound should show more, and the fact remains that a steam locomotive under the best conditions, has developed a dynamometer horse power hour at a coal consumption of 2¼ to 3½ pounds, corresponding to a total efficiency of 4.9 to 7.5 per cent.

Actual Efficiency of Locomotives in Service.

We have found therefore that in order to realize what are avoidable and what are unavoidable losses in the conversion of heat into work by a steam engine or locomotive, that it is necessary to consider first what degree of economy could be obtained by an ideal steam engine working under certain limiting conditions, and then consider with what perfection our existing locomotives approach that ideal. Locomotives do not, however, operate upon testing plants, but in hauling trains, and the real point we are interested in is the extent to which our locomotives in actual service approach the best results that it is possible to obtain. We know that on the testing plant the machinery was in the best possible condition, the boiler was not leaking, the valves and pistons were as tight as they could be made, and the firing was as good as it could possibly be. To what extent do we approximate the testing plant results and how does our actual efficiency compare with that obtained upon them?

Unfortunately when we are dealing with road conditions there are a number of factors to be considered that cannot be accurately allowed for. In place of constant conditions there are exceedingly variable ones; part of the time the engine is running and part of the time standing, and any comparison that can be made must necessarily be more or less approximate. No estimate can be made that is a reasonable one for determining the exact consumption of the engines in pounds of coal per dynamometer horse power hour, but one figure can be obtained with reasonable accuracy, namely, the efficiency of the equipment and organization as a whole. If in place of the ideal steam engine we consider the best results obtained upon the testing plant as the ideal locomotive efficiency, we can determine fairly closely the degree to which such an ideal is approached by our locomotive and operating departments. To do this some particular section or division must be selected, and for this purpose I will refer to the results obtained on District 1 of the Central division on the Canadian Pacific Railway during the last few months. On that district the fuel consumption has for several months been below 80 pounds per thousand equivalent gross ton miles. In one month it was 75 and in another 76, and these figures are not taken from any particular test but represent the total consumption on the division, averaging over 7,000 tons of coal per month. When it is considered that, although the difference in level of the two ends of

this division of 420 miles is small, only 150 feet, the heavier tonnage is uphill, it is doubtful whether this result has ever been equaled in this or any other country, especially where the large amount of traffic which it includes is taken into account. It is therefore a good example to consider for comparison with an ideal engine, but on account of the hill condition on the east end, the section from Ignace to Winnipeg is preferable in place of the entire district.

The coal records available on the road show the total coal consumed per 1,000 equivalent gross ton miles, and cannot therefore be directly compared with the coal per dynamometer horse power hour. Supposing, however, a train had an average resistance over a division of five pounds per ton, so that 1,000 tons gave a resistance of 5,000 pounds. This 5,000 pounds pulled one mile, or 5,280 feet, would equal 26,400,000 foot pounds. A horse power hour is 1,980,000 foot pounds, so that 1,000 ton miles with a train having a resistance of 5 lbs. per ton is the equivalent of 12.8 horse power hours. This is evidently proportional to the resistance, so that if the average resistance of the train was 10 lbs. per ton, 1,000 ton miles would equal 25.6 horse power hours and so on.

I cannot give the exact figure for the resistance of a train from Ignace to Winnipeg, but the figure obtained for a very similar

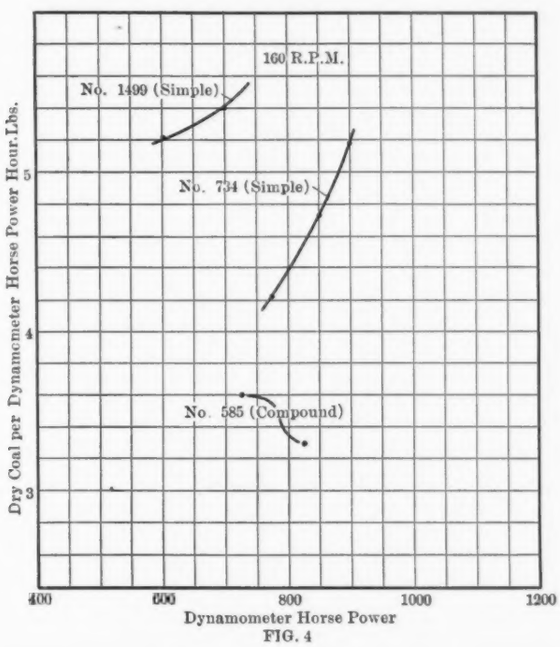


FIG. 4

district, Outremont to Smith Falls, was 4.50 lbs. eastbound and 7.00 pounds westbound. The difference in level is 2.6 feet per mile which accounts for 1 lb. per ton from an average of 5½. From other figures we have I believe the figures of 7 lbs. per ton is slightly high and that figure for a level undulating road with short grades not exceeding 0.5 or 0.6 per cent. would be about 5½ lbs. The difference in level would increase this to 6½ lbs. up hill and reduce it to 4½ lbs. down. Now from Ignace to Kenora the grade averages 2.7 feet per mile down westbound, and from Kenora to Winnipeg 2.53 feet per mile down westbound, so that with very little danger of inaccuracy we may say that the average resistance is 4½ lbs. per ton west and 6½ lbs. per ton east bound on these two sections. One thousand ton miles is therefore the equivalent of 11.5 and 16.6 horse power hours respectively, and if we assume that when working, the ideal engine has a speed of 20 miles per hour corresponding to a coal consumption of 2.7 lbs. per dynamometer horse power hour, the coal required per 1,000 E. G. ton miles would be 31 and 44½ respectively.

Taking the month of July this corresponds with *actual results of 61 and 86½ lbs., or an efficiency of 51 per cent. in both cases, and this in a sense may be said to be the efficiency of the operation as a whole.* This, however, is not exactly fair, it does not mean that the ideal engine could possibly do the work on 51 per cent. of the coal. On the testing plant, the fire is in good condition when the test is started and finished, the engine does not have to turn a wheel except the drivers, there are no air pumps or electric headlights to run, while on the road every pound of coal has to be accounted for, and the resistance of the engine is, even when the machine friction is deducted, certainly equal to that of the train. Suppose we consider our ideal engine under these conditions. The average length of the sections is 139 miles, the amount of coal lighting up, and that which must be knocked out at the end of the run, is about 2,000 lbs. If we assume that the average length of trip is 10 hours and the air pump takes 30 double strokes a minute during that time, on a full train, the air pump will take about 2,000 lbs. of coal westbound, and 1,100 lbs. eastbound. The headlight requires 60 lbs. of coal per hour and if burned 6 hours out of 24, or 25 per cent. of the time, will average 150 lbs. per trip. We have therefore 4,150 lbs. westbound and 3,250 eastbound per trip required by the road engine, or 30 and 23 lbs. per mile respectively. We have in addition to allow for the power required to draw the weight of the engine, so that making these allowances the coal required by an ideal engine would be as follows:—

Westbound.	Per 1000 ton miles for actual power developed.....	31. lbs.
	Additional for weight of engine.....	2.1 lbs.
	Additional for air pump, etc.....	13.9 lbs.
	Total	47.0 lbs.
Eastbound.	Per 1000 ton miles for actual power developed.....	44.5 lbs.
	Additional for weight of engine.....	5.3 lbs.

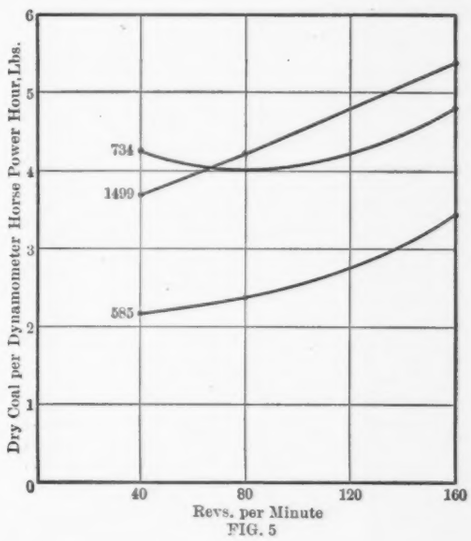


FIG. 5

	Additional for air pump, etc.....	18.8 lbs.
	Total	68.6 lbs.

The net efficiency obtained therefore is 77 per cent. and 79 per cent. respectively, or considering the roughness of this calculation, about 75 to 80 per cent. This appears to be a very creditable record. We do not, of course, know whether the engine is as economical as that at St. Louis, but we have had almost exactly similar engines on this road and have found that under favorable conditions their economy is practically the same as that of the D 10 class which were in use on this district, while under other conditions the D 10 were superior. We may safely say, therefore, that this district has come within 25 per cent. of testing plant conditions, so far as we know them, and to you gentlemen, members of this club, who are also engaged in this work, I can only say that you have done well, but let us get after that other 25 per cent.

TRAIN DESPATCHING BY TELEPHONE.—The Norfolk & Western will soon have telephones in use for train despatching throughout its main line from Norfolk, Va., to Columbus, Ohio, about 700 miles. On some divisions the telephones have been in use many months and the others are to be equipped soon.